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Bascule Bridge At Ashtabula Harbor.

ELECTRICALLY OPERATED "HEEL TRUNNION" BRIDGE.—[See page 172]

The Ultra-Microscope*

And Its Application to the Study of Colloids

By E. Jobling

It is often imagined, by those unacquainted with either of the sciences of light and microscopy, that it is merely a question of difficulties in construction of the microscope, particularly of the lenses employed, which prevents us from perceiving the very smallest of objects by its aid. Such, however, is not the case. At certain definite limits of size, phenomena intervene which effectually mar every effort at the microscoping of objects with diameter below this limit. The root of the difficulty lies in the phenomenon of light itself. The fact that light is a transverse vibration of appreciable wave length is of slight importance when dealing with the common objects of everyday experience, but immediately the attention is turned to objects of size comparable with this wave length, the mechanism of light propagation assumes tremendous significance. Then it is that the ordinary laws of reflection and refraction are waived in favor of the more subtle, and therefore the more interesting phenomena of diffraction.

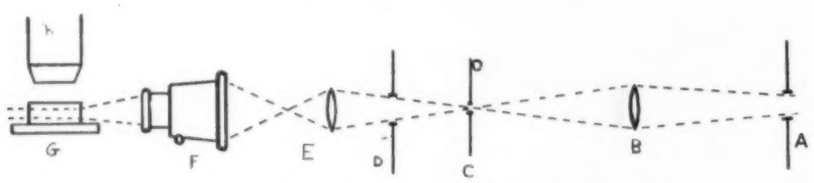

Fig. 1.—General Arrangement of the Optical System for Illuminating the Field of the Ultra-microscope.

On the common sense principle that a sea wave is but little disturbed by a pebble, though profoundly modified when brought up against a sea wall, it seems reasonable to assert, without further explanation, that an object comparable in size with a wave length of light cannot be expected to reflect waves which could convey to the eye a distinct impression of its size and shape. True, it does effect a minute disturbance, but of this more anon. Without venturing into a mathematical discussion of a microscope's "resolving power," it will be sufficient to state that one cannot hope to perceive an object whose size lies below one quarter of a wave length of light, this constituting the limit above referred to.

However, fortunately or unfortunately, scientists have interest in objects much smaller than these. Thus, the ever-increasing subject of colloids demanded an instrument for the direct observation of colloidal particles; and bacteriology, again, found itself hampered for want of a means of visualizing the cells and microbes with which it is concerned. The difficulty has been happily surmounted by the introduction of the ultra-microscope, an instrument which, as its name implies, renders it possible to demonstrate to the eye the existence of objects invisible ordinarily to the finest microscope.

This does not imply that the ideas put forward as to the limits of optical resolution have been in the least contradicted, as the following consideration will show. To be seen, an object must either reflect the light by which we see it or be self-luminous. Consider only a very small particle. If it be of a magnitude above the optical limit, it may be seen by virtue of the light it reflects, and its true form can then be perceived. If, however, its magnitude be below this limit, reflection is impossible, and all incident light becomes diffracted, i. e., scattered in all directions. In the latter case, the object emits light exactly as though it were luminous of itself, though under ordinary circumstances it remains invisible because the proportion of light reaching the eye with regard to the incident light is so small. If now means be adopted for concentrating light upon the object, it might be possible, other circumstances being favorable, to make it emit sufficient light to reach visibility. Of course, the object then cannot be seen in the sense that its shape or surface can be observed, but only seen in the sense that its presence is indicated by the light it emits, being observed in the microscope as a minute disk of light. The utilization of such a concentrated illumination is the fundamental idea underlying the construction of the ultra-microscope.

This principle was foreshadowed by a phenomenon observed long ago by Tyndall, who passed an intense beam of light through the air of an otherwise darkened chamber, when the track of light was made clearly visible by the light diffracted from the minute dust-motes floating in the atmosphere. Ultra-microscopy furnishes an extension of this, a microscope being introduced for the fuller examination of the track of light. Thus, Zsigmondy, in 1900, as part of his observations on some colloidal gold solutions, reflected a cone of light into the solution and examined the apex of the cone through a microscope. Working on the same principle, Siedentopf was led in 1903 to the improvement of the apparatus, with the result that we owe to him the introduction of the modern high-power illuminating arrangements which form the main feature of the instrument.

Naturally, certain conditions require to be fulfilled. In the first place, the most intense illumination possible is necessary to render the smaller particles visible; secondly, to prevent dazzling of the eye and consequent inability to detect the minute light disks, no illuminating ray must be allowed to fall upon the eye either directly or by reflection; thirdly, in view of the often extreme faintness of the light disks, the darkest possible background is essential; and lastly, the beam of light must be extremely shallow in the direction of the line of sight, else nothing more definite would be observed than a luminous haze. Only by rigid satisfaction of these conditions can definite results be obtained.

In the light of the above requirements, the following diagrammatic arrangement of the apparatus constituting one of the most delicate forms of the ultra-microscope and seen in Fig. 1 will be considered. The solar rays are reflected from a heliostat through the slit *A* into the darkened laboratory in which the apparatus is set up. The light falls on to *B*, a telescope objective, by which it is concentrated on to the slit *C*, which is capable of very fine adjustment. *D* is a screen with an aperture of sufficient size to cut off any stray rays of light reflected from the edges of the slit. Another objective, *E*, directs the light into the condenser *F*, from which it passes as an intense beam into the solution contained in *G*. At right angles to the path of light is arranged the microscope *H* for minute examination of the track of light in *G*. This latter cell, for the use of solutions, usually takes the form shown in Fig. 2, the rectangular part *K* having quartz faces and being fitted also with a funnel and outlet, which permit of easy washing and filling without disturbing the adjustment.

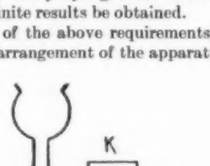

Fig. 2.—Cell for Examining Liquids.

Fig. 3.—Illumination by the Method of Cotton and Mouton.

The above design by Siedentopf of the ultra-microscope is not the only one which has been used. A simpler device, due to Cotton and Mouton, is worthy of note. An oblique parallelopiped of glass, surmounted by the solution and cover slip, is placed upon the stand of the microscope. The convergent illuminating beam follows the course shown in Fig. 3, the angle of incidence on the upper surface being adjusted to lie between the critical angles for water-glass and glass-air surfaces and the beam, therefore, is totally reflected. Then, the only light which enters the microscope *H* is that diffracted by the ultra-microscopic particles of the solution.

For the examination of larger particles, e. g., cells, bacteria, and so on, modified forms of the apparatus may be employed, in which, for convenience, the illuminating rays and the rays diffracted from the particles are in the same straight line. But as these would require complicated designs and descriptions, their consideration is omitted.

To understand at all completely the beauty of this apparatus, resort must be made to a consideration of several of its more interesting applications. Its possible service to the colloidal chemist and to the bacteriologist has already been hinted at, and we cannot do better than turn our attention to at least one of these applications. Before so doing, a few figures indicating the degree of sensitiveness as compared with other methods of analysis might be deemed interesting. By the aid of spectrum analysis, Bunsen and Kirchhoff consider that 0.14×10^{-6} milligramme of sodium can be detected; while, in the case of hydrogen, Emich avers that as minute a quantity as 0.7×10^{-12} milligramme gives appreciable indication of its presence. Again, it is asserted by Fischer that by the sense of smell 2.2×10^{-9} milligramme of mercaptan and by Berthelot that 10^{-11} milligramme of iodoform are capable of detection, though here the examples are far and away among the most exceptional that could have been chosen. In the chemical way, too, 3×10^{-7} milligramme of sodium hydroxide are able to produce a definite change in the color of some suitable indicator. With the ultra-microscope, however, a particle of gold of mass 10^{-15} milligramme in a gold ruby glass may be observed without trouble, while when the most favorable conditions are available, a particle of size ten times that of an average chemical molecule will not escape observation. Obviously, the potentialities of the instrument are great and there is no saying what more astounding results may be expected when the method is still further improved.

Application to the Study of Colloids.

No more fascinating field of inquiry is open to science than the investigation of so-called colloidal solutions. That such a substance as platinum, for instance, generally regarded as insoluble in water, should be capable of forming what appears to be a solution, is certainly striking on first acquaintance. Not only metals, however, but many "insoluble" substances, like silver chloride, can be made to develop this peculiar state by suitable methods. Natural colloids are of universal distribution, the very constituents of living cells appearing to exist in such a form. The properties of a colloidal solution afford a striking contrast to those of ordinary solutions; for instance, their slight ability to diffuse and consequent separation from truly soluble salts by dialysis, their insignificant osmotic pressure, their peculiar electrical properties which seem to point to the presence of an electric charge upon the particles, their capacity for coagulation and absorption, and so on. All these circumstances add an interest to the study of colloids which has served to attract a great host of investigators, as will be gathered from the enormous output of work upon the subject.

Much controversy has been waged over the exact nature of these colloidal solutions, for they bear intimately upon the problem of solution in general. Many investigators have been inclined to the idea that they represent perfect solutions, while others identify them as suspensions. The intervention of the ultra-microscope has contributed largely to the development of the question, if not to its final solution.

With one or two exceptions, all colloidal solutions on ultra-microscopic examination are found to contain distinct particles, which reveal themselves, as already stated, in diffraction-patches on a grey background. These particles can be counted and their size calculated. There is thus strong evidence for regarding a colloidal solution as merely a limiting case of a suspension. A crystalloidal solution, i. e., the solution of a substance like sodium chloride, gives an absolutely clear field, and one, therefore, infers the absence of even the tiniest particles in a solution of this type. Such a conclusion, however, is questioned by the observations of van Calcar and de Bruyn, who found, for example, that rapid centrifugalization of a sodium sulphate solution induced partial separation of the salt. From the above reasoning, and further observation but confirms this, it seems impossible to draw any sharp line of demarcation between suspensions, colloidal and crystalloidal solutions, the one class merging imperceptibly into the other. Ultra-microscopic study shows over how wide a range the size of the particles in a colloidal solution varies and renders any attempt at classification of solutions still more un-

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satisfactory. Indeed, it seems probable that in a solution the size of the "dissolved" particle can vary gradually from that of the ordinary chemical molecule to the dimensions of a visible suspensoid particle, the properties of the resulting solutions varying with the molecular forces called into play.

But more interesting developments even than these can be attributed to the ultra-microscope, for results recently obtained by its aid go far toward strengthening the probability of the Atomic and Molecular Theories. Over a century ago, the naturalist Brown observed that the particles of a fine suspension, when observed under the microscope, are in a continual state of agitation, but the observation was shelved and almost forgotten. It is only in recent years, and mainly by the application of the ultra-microscope, that the further investigation of this interesting phenomenon has been rendered possible.

The ultra-microscope has demonstrated that the smaller the particle the greater the activity, until in colloidal solutions we get a movement so violent as to resemble, in the words of Zsigmondy, "a swarm of dancing gnats." There seems to be some connection between this rapid movement of small bodies and the slower movement of the heavier particles observed by Brown. Indeed, it almost suggests that, if further diminution of the particles be imagined, the attainment of molecular dimensions might give a value for the molecular velocity of an order comparable with that calculated on the theoretical assumptions of the Kinetic Theory; in other words, that the kinetic energies of a molecule and of a colloid or suspensoid particle are equal. This view has developed almost into a certainty, particularly by Perrin's remarkable investigations, and an experimental verification of the Kinetic Theory is thus forthcoming.

A brief outline of Perrin's work will serve not only as a development of the above brilliant idea, but also as a fitting demonstration of the methods employed in ultra-microscopic research.

In the first place, his investigations required a colloidal solution, the particles of which were of the same size, and this was rendered possible by the method of "fractional" centrifugalization. The uniform solution, after dilution and standing for some time, was then examined ultra-microscopically, the microscope being focussed on an extremely shallow beam of light capable of vertical movement. At positions corresponding to different heights of the solution, an estimate of the number of particles was accurately made. This, of itself, is an extremely laborious undertaking. The particles illumined by the beam are visible in the field of the microscope, but are executing their Brownian dance, and it is impossible to make even an approximate computation of their number. The difficulty is overcome by the use of one of two methods. Either the field of view is instantaneously photographed several times and the mean number taken; or a stop is inserted in the microscope so as to limit the field to contain only a few particles, and then, by means of a shutter, instantaneous "peeps" are obtained at small intervals, the number of observed particles being noted at a glance, and subsequently the mean of several thousand of these readings taken. Both methods give very concordant results. Having ascertained the number of particles corresponding to different heights in the solution, examination showed that these were, within the limits of experimental accuracy, exactly in geometrical progression.

Thus, at heights 100 75 50 25 microns,
the numbers 200 170 146 116 were obtained,
while 201 169 142 119 are in exact geometrical progression. Such results demonstrated beyond doubt that the particles reach a state of equilibrium where their distribution corresponds to that of the molecules of a fluid. Thus, in the atmosphere, the concentration of the constituents gradually diminishes as we ascend, the diminution obeying the above exponential law. The only difference between the two cases is that while the atmosphere requires a rise of six kilometers for the halving of the concentration, a colloidal solution requires about one tenth of a millimeter.

Having proved that such an experimental law was applicable to colloidal solutions, a mathematical expression was easily deduced by which, given the density of a particle, its mass and the number per unit volume, the Kinetic Theory constant—which denotes the number of molecules per gramme-molecule of any compound—is calculable. For the present purpose it is not necessary to go into the mathematics of the case. Sufficient that the mass is now the only unknown which prevents us from solving the problem, and this is deduced by the application of Stoke's law, which gives an expression for the velocity of a sphere as it sinks through a viscous fluid. The velocity of fall of colloidal particles in a capillary tube, as they descended to take up their final distribution, was carefully observed and by substitution in Stoke's equation the mass of the particles calculated.

Everything is now ready for the determination of the Kinetic Theory constant. On the basis of this theory, the constant has been worked out to be 7×10^{-22}. Judge of the interest and importance of the above investigation, absolutely experimental throughout, when the value of the constant was found to be 6.9×10^{-22}. Since then, more accurate determinations have been made and it seems that the above method comprises a means for the determination of that fundamental constant, the number of molecules per gramme-molecule, which is capable of almost unlimited precision. The gas laws, already applied by van't Hoff to dilute solutions, are thus extended by Perrin to uniform emulsions.

The Nitrogen Enrichment of Soils*

In a paper recently read before the Royal Society of Canada the authors gave a summarized account of the experiments that had been conducted by the Chemical Division of the Experimental Farms since 1889 in the very important matter of the nitrogen enrichment of soils ("Experimental Work towards the Nitrogen Enrichment of Soils," by Frank T. Shutt, and A. T. Charron.

The first fact brought forward was that rich productive soils are characterized by a high nitrogen and humus content. Evidence was adduced to show the correctness of this statement, not only from the examination of cultivated soils of first quality and established high productiveness, but from many analyses of soils of the virgin prairie of the North-Western provinces so widely recognized for their wonderful fertility.

On the other hand, soils naturally poor and those impoverished by irrational farming have been found to be low in nitrogen and humus forming material. The semi-decomposed vegetable matter of the soil is the natural storehouse of its nitrogen, and experimental proof had been obtained that demonstrated beyond question that humus forming material must be constantly added to cultivated soils if their nitrogen content and their productiveness were to be maintained. The grain growing of the West, which implies fallowing and no formation of a sod, was very destructive of humus and nitrogen, and must in time seriously impair the richest soil. The rational and economic upkeep of soil fertility demands the keeping of stock for the production of manure—the most important natural source of humus and nitrogen for farming lands—and a proper rotation of crops; that is, one which will periodically enrich the soil, as by the growth of a legume, in these valuable constituents.

Nitrogen is the dominant element among those furnished by the soil, and its amount and availability in a very large measure determine crop yield. The investigations discussed in this paper were instituted to learn the extent of the depletion of the soil's nitrogen by cropping and cultural operations, how far the legumes (clover, alfalfa, vetch, etc.) could be utilized on the farm for the increase of the soil's nitrogen and the furnishing of humus forming material, and finally to ascertain what the practical value might be of inoculation (*a*) with "cultures," and (*b*) with soil from fields bearing a leguminous crop for the encouragement of the growth of these plants.

DEPLETION OF SOIL NITROGEN.

It was found from the examination of a soil which had never received manure and which had been under cultivation for twenty-two years, during which period it had borne six crops of wheat, four of barley, and five of oats, with nine summer fallows (bare) during the latter seventeen seasons, that the loss of nitrogen to a depth of 8 inches amounted to 2,206 pounds per acre. Of this, approximately 700 pounds had been removed in crops. This means that about 1,500 pounds per acre, or 68 per cent of the total nitrogen lost, had been dissipated during this period through cultural operations, fallowing, etc. The soil experimented with was an exceedingly rich prairie soil in Saskatchewan. Very probably it is a type of soil that would at first lose nitrogen more rapidly than one of a poorer quality, and, further, undoubtedly, fallowing is of all operations the most wasteful of soil fertility, but the figures are significant in showing there is an inevitable and heavy depletion of the soil's most valuable constituent, consequent upon the necessary tillage of the land. Our soils, then, must be constantly replenished with organic matter if they are to be kept productive and profitable.

LEGUMES AS NITROGEN ENRICHERS.

As is well known the legumes are very rich in nitrogen, and as a part of this nitrogen at least is obtained from the atmosphere, they as a class are extremely valuable as manurial agents. The more important leguminous crops, clovers, alfalfa, vetches, peas, beans, etc., were grown and analyzed, the weight and nitrogen content of stem, leaves, and roots per acre being determined. The clovers and alfalfa were found to be the most valuable, chiefly by reason of their larger root system, in which might be stored from one third to one half the total nitrogen in the crop. By the turning under of a fair growth of one of these crops, from 100 to 150 pounds of nitrogen may be added to the soil per acre, an amount equivalent to that furnished by an application of 10 tons of ordinary barnyard manure.

The details of an interesting and valuable experiment were given, in which by analysis of the soil "before and after" the amount of nitrogen which had become part and parcel of the soil through the growth of clover was determined. A plot of very light sandy loam was first seeded with clover in 1902. Every second year from that date until the present time the plot had been dug over and re-sown. No manure at any time was used, but phosphoric acid and potash were furnished at the outset by a moderate dressing of superphosphate and muriate of potash. The soil was sampled and analyzed six times during the experiment period. The data show that the nitrogen content had practically doubled in the nine years despite the losses from bacterial activity and other causes. The soil to a depth of 4 inches contained at the beginning of the experiment (1902) 533 pounds, and at the close (1911) 1,005 pounds per acre. If it is assumed that the growth of the clover had added annually nitrogen at the rate of 100 pounds per acre it will be observed that the loss due to oxidation, etc., during the experiment period almost equalled the gain.

If the clover had been cut and fed, the manurial value of the residues (roots, decayed leaves, etc.) would have been almost one half that here recorded. These data afford satisfactory evidence as to the value of a leguminous crop in the rotation, if soil fertility is to be economically maintained.

INOCULATION EXPERIMENTS.

The special value of the legumes as nitrogen enrichers is due to the fact that they are able to draw upon the free nitrogen of the atmosphere for a part of their supply. Thus, instead of impoverishing the soil's store like all other crops, they add to it. The appropriation of free nitrogen does not take place directly, but is accomplished through the agency of certain bacteria present in the soil, which attach themselves to the roots of the legume, with the result that nodules or tubercles are formed thereon in which they reside. In some way, not as yet clearly understood, nitrogen compounds are formed within these nodules, and enter into the circulation of the host plant, to be built up into its tissues of root, stem, and leaf. It is the nitrogen of the air existing in the interstices of the soil that these special nitrogen-fixing micro-organisms utilize, and this points to the desirability of a well drained, well aerated soil if these bacteria are to perform their beneficial function. Without the aid of these specific bacteria the legumes cannot avail themselves of the free nitrogen of the air, but like other crops draw upon the nitrates of the soil for their nitrogenous food. Legumes, therefore, in the absence of these germs are not nitrogen enrichers of the soil. Are these nitrogen-fixing bacteria universally present in the arable soils of the Dominion? We cannot say that they are, though the examination of the roots of legumes collected in various parts of Canada has shown by the nodules thereon that these micro-organisms are very widely distributed over the Dominion. Our observations have made very clear that failure to obtain a good catch and growth of clover is not always to be attributed to the absence of the necessary bacteria, but in many instances is due rather to an unfavorable mechanical condition of the soil, inadequate drainage, deficiency of moisture, acidity or sourness of the soil denoting the need of lime, or finally to poor seed.

To furnish the farmers with the means of introducing the nitrogen-fixing bacteria, where their absence is suspected, "cultures" of these bacteria have been prepared and put on the market. Their use is known as inoculation. During the last twenty years a considerable number of these cultures or preparations, from Germany, United States, and home sources, have been tried on the Experimental Farms, and at other points. Specific cultures for clover, alfalfa, peas, beans, etc., have been experimented with. While in many instances they distinctly favored the growth of the legume, their action on the whole was more or less uncertain. The profitable employment of these preparations seems therefore problematical. All the failures met with were not attributed to lack of vitality in the cultures, but it was evident that their usefulness is much impaired by age, light, and heat, and unless prepared by a reputable firm or institution, and still fresh, good results can scarcely be looked for.

The employment, as an inoculating material, of the soil from the surface of a field bearing a luxurious crop of the specific legume had given much better results than the use of cultures, and this method, where cost of transportation is not too great, will be found the most reliable for the general farmer. Notable instances of successful inoculation by this method, applying the soil at the rate of 100 to 300 pounds per acre, were recorded for alfalfa in the North-Western provinces. Inoculation, as has been said, is not generally necessary, but where it is considered indispensable by reason of the absence of the nitrogen assimilating bacteria, a supply of this bacteria-laden soil will, it is believed, prove more effective than the use of a culture.

* A contribution from the Chemical Division, Dominion Expt. Farms, Canada, published in the *Chemical News*.

Sir William Herschel*

The Greatest Telescopist of All Times

By Prof. G. H. Darwin

DURING the last twenty years there has been a great revival of statistical investigations as to the distribution and motions of the so-called fixed stars. Kapteyn, of Groningen, is the leader of those who are renewing the attempt to obtain in this way some idea as to the construction of the universe. Earlier astronomers had of course done something in this direction, but the work of William Herschel so far transcends that of all others, that it would be fair to describe him as the originator of this class of investigation. It may be of interest to mention that a complete edition of his works is now in course of publication, under the direction of a joint committee of the Royal and Astronomical Societies.

The interest of Herschel's writings, and the simple charm of his style—written it is to be remembered in a language which was not his from birth—have led me on to read about the man as well as about his scientific work. Throughout his life's work his name is inseparable from that of his sister Caroline, and I hope it may prove of interest to you to hear of what they were as well as of what they did. They were born at Hanover, he in 1738, she in 1750, the children of a bandsman of the Hanoverian Guards. At the age of fifteen Herschel was already a member of the Guards' band. In 1757 the regiment, which had been in England for about a year, served in Germany during the Seven Years' War, and William seems to have suffered from the hardships of the campaign. His parents, seeing that he had not the strength for a soldier's life, determined to remove him from the regiment. The removal may be described more bluntly as desertion, for we learn that when he had passed the last sentinel at Herrenhausen, he took off his uniform and his luggage was secretly sent after him to Hamburg. At any rate, fortunately for science, he escaped, and in 1757 or 1758 made his way to England.

It would perhaps be impossible to follow him throughout his wanderings, but we know that he was at one time instructor of the band of the Durham Militia, and afterward that he gained his living as a musician in Leeds, Halifax, Pontefract and Doncaster. In 1764 he even ventured back to Hanover for a short time, and thus saw his favorite sister again.

In 1766 William took a position as organist at Bath, then at the height of fashion.

On Mr. Linley's retirement from the orchestra at Bath, Herschel became the director and the leading music-master in the town, and he thus obtained an established position. Caroline, who had by this time joined her brother, sang a little in public but her aspiration to become the prima donna of Bath was not fulfilled. But she was kept busy enough at first in the cares of housekeeping, and then she gradually became more and more her brother's astronomical assistant.

In the midst of Herschel's busy musical life he devoted every spare moment to astronomy, and when his negotiations for the purchase of a small reflecting telescope failed—and they were all small in those days—he set to work to make mirrors for himself.

In order to learn anything of the making of reflectors it is necessary to go to original memoirs[1] on the subject, and even of them there are not many. Mirrors are now made of glass with a reflecting surface of chemically deposited silver; formerly they were made of speculum metal, an alloy of copper and tin. Of whatever substance the mirror is made the process of working it to the required form is much the same. The most complete account of the process of which I know is contained in a paper by Prof. G. W. Ritchey in Vol. 34 (1904) of the Smithsonian Contributions to Knowledge. He there gives a full description of the great reflector of the Yerkes Observatory. The process only differs from that employed by Herschel in that he worked by hand, whereas machinery is now required to manipulate the heavy weight of the tools. The Yerkes mirror is formed of a glass disk 5 feet in diameter, and it weighs a ton; the grinding tools are also very heavy.

It will be well to begin by an account of the manufacture of the tools wherewith the finer grinding and polishing is effected, and then I shall pass on to a short description of the way they are used.

Two blocks of iron are cast with the desired radius of curvature, the one being concave and the other convex. The castings are then turned so that the concavity and convexity fit together as nearly as may be. For the large mirror these blocks are a little over 2 feet 6 inches in diameter, but for small ones they are made of the same diameter as the mirror to be ground. The two are then ground together for a long time with emery powder and water until every part of one surface fits truly to every part of the other. They must then both be portions of a sphere or the same radius, because the sphere is the only surface in which a universal fit is possible. The concave iron is very precious because it furnishes the standard for regrinding the convex grinding tools when they have become worn by use. In order to make a plane mirror, three surfaces are ground two and two, for if *A* fits *B* and *C*, and *B* fits *C* all over each surface they must all be true planes. However, I shall only speak of the figuring of concave mirrors.

The roughly hollowed glass disk is now laid on several layers of Brussels carpet centrally on a massive horizontal turn-table. The convex iron tool just described is suspended by a universal joint from a lever, and it is counterpoised so that only a portion of the weight of the tool

Sir William Herschel.

will rest on the glass when it is in use. A complicated system of cranks and levers is so arranged that the tool can be driven by machinery to describe loops or curves of any arbitrarily chosen size over the glass, and as these loops are described by the tool the turn-table turns round slowly. In this way every part of the tool is brought into contact with every part of the glass disk in a systematic way. When working near the edge a large part of the tool projects beyond the edge of the glass.

Emery powder and water are supplied in a way I need not describe, and the tool is lowered gently on to the glass. The motive power is then applied, and the grinding is continued for many hours until the preliminary rough depression has been hollowed to nearly the desired shape, namely, that of the standard concave iron.

For finer grinding a change of procedure is now adopted, and very finely powdered emery is used. Another convex tool is formed, by grinding with the standard concavity; the working face of the tool is, however, now cut up into small squares by a criss-cross of narrow and shallow channels. Such channels are found to be necessary in order to secure an even distribution of the emery and water all over the surface. The grooved tool is now used for many hours, and the surface is tested at frequent intervals with a spherometer. The work ceases when it is no longer possible to detect errors of curvature in this way.

The next stage is polishing. The thickness of the layer of glass worn off in polishing is to be estimated in ten-thousandths of an inch, and can scarcely be detected even with the finest spherometer. For polishing the iron tool is discarded and the work is carried on by hand. As lightness is essential, the tool is built up by a stiff lattice-work of wood with a continuous wooden working face. It is obvious that however carefully the face may be turned it can not be made sufficiently true, and the requisite accuracy is obtained by means of the plastic properties of rosin or pitch. A number of squares of rosin about a quarter of an inch thick and an inch square are made, and these are glued in rows on the convex face of the wooden tool, with a narrow space intervening between each rosin square and its neighbors. The tool is then warmed slightly so as to soften the rosin a little, and it is then pressed lightly on to the glass disk. By means of this "warm-pressing" a nearly perfect fit is attained.

Each of the rosin squares is then painted with hot melted wax. This is done because wax is harder than rosin and affords a better working face. Finally, when the tool is quite cold, the surface of the glass is painted all over with very finely powdered rouge and water, and the tool is placed gently on the glass with some additional weight resting on it. It is left thus for several hours, but is moved slightly every ten minutes to insure an even distribution of the rouge and water. By means of this "cold-pressing" a perfect fit is secured of the wax-coated rosin squares with the glass face. Cold-pressing has to be repeated every day before the work begins.

The polishing is now carried on in much the same way as the grinding, but by hand instead of by machine power. The turn-table can be made to tilt so as to bring the glass to stand vertically, instead of horizontally, and the disk is frequently tilted up so as to submit the surface to optical tests. These latter tests are far more searching than those with a spherometer, and enable the observer to detect an error in the radius of curvature of portion of the reflector of a hundredth of an inch. To correct such an error it will be necessary to remove a layer of glass of 1/500,000 of an inch!

The most refined optical test is by the observation of the image of a brilliant light issuing from a pin-hole close to the intended center of the spherical surface. The observer examines the image of the pin-hole with a microscopic eye-piece placed as close as possible to the pin-hole. He then causes a straight-edge close in front of the eye-piece to move slowly across the reflected beam of light, either from left to right or from right to left, so as to eclipse the light. Previously to the eclipse the whole of the glass seems to be a uniform blaze of light, and if the curvature is perfect the light which enters the observer's eye comes from all parts of the disk, and the surface is seen to darken equably all over. But if the surface is imperfect the light from some part is eclipsed sooner than that from others, and the disk seems to possess considerable hills and valleys illuminated, as it were, by a setting sun.

The interpretation of these apparent hills and valleys shows where further local polishing with a small tool is requisite. Sir Howard Grubb says that if he suspects a hollow, he holds his hand near the surface for a minute or two; if a hill is suspected, he washes the region with an evaporating wash. The warmth in the one case and the cooling in the other tend to rectify, and indeed over-rectify, the errors.

When success is finally attained, after all we have only a spherical surface, and it becomes necessary to obtain a parabolic form. This last stage is done by further tests of the kind described, with a diaphragm placed over the mirror which only permits the observer to see the light reflected from chosen zones of the mirror. The time at my disposal will not allow me to describe this in further detail, or to tell you how there is always found to be one definite diameter of the glass along which its weight must be supported. I must pass by, too, the system of counterpoised levels used for supporting the back of the glass, and the method by which silver is chemically deposited on its surface. Meager although this sketch has been, it will have served to show you how beautiful are the processes employed, and I would ask you to realize that at first Herschel was a mere amateur, and had to discover everything for himself.

As I have said, Hershel had to do all his polishing by hand, and he found when once the final stage had begun, it was necessary that it should never stop even for a moment. Caroline relates how she was kept busy in attending on her brother when polishing:

"By way of keeping him alive I was constantly obliged to feed him by putting the victuals by bits into his mouth. This was once the case, when in order to finish a 7-foot mirror, he had not taken his hand from it for sixteen hours together."

The incessant work, together with the interruptions

* An address before the Royal Institution of Great Britain, given on April 26th, 1912, and published in *Science*.

[1] Sir Howard Grubb's lecture at the Royal Institution in 1887 is one of these, Vol. XI, p. 413. Lord Rosse's papers are among the most important.

by many and frequent visitors, began at length to tell on Herschel's health. His sister notes that on the 14th of October, 1806, after working all day, he was out from sunset till past midnight surrounded by fifty or sixty persons, without food or proper clothing, and that he never seemed to recover completely from this great strain on his strength.

Although Herschel lived until 1822, and accomplished an enormous amount of work up to the end of his life, yet his health seems to have declined from about this time on. On his death Caroline felt that her life, too, was practically ended and she returned to Hanover. Ever afterward she used to cry, "Why did I leave happy England?" and it is incomprehensible that she should not have returned to the place where all her real interests lay. She died in 1847, having very nearly completed her ninety-eighth year.

Herschel himself must have been a man of singular charm, as is testified to by Dr. Burney and his daughter Mme. d'Arblay. That he possessed an incredible amount of patience is proved by the fact of his submitting to the reading aloud of the whole of a portentous, and fortunately unpublished, poem in many cantos by Dr. Burney, entitled "A Poetical History of Astronomy." It appears that Herschel had had an interview with Napoleon in Paris in 1802, and the poet Campbell asked him whether he had been struck by Napoleon's knowledge. Said Herschel:

"No, the First Consul surprised me by his versatility, but in science he seemed to know little more than any well-educated gentleman, and of astronomy much less, for example, than our king. His general air was something like affecting to know more than he did know."

He was struck, too, by Napoleon's hypocrisy in observing "how all these glorious views gave proofs of Almighty Wisdom."

And now having endeavored to show what kind of people Caroline and her brother were, I must turn to what they did. Herschel's discoveries were so numerous that I am compelled to make a selection. I shall therefore only attempt to sketch his endeavor to understand the general construction of the stellar universe, and to speak of his work on double stars.

The only general test of the relative nearness or farness of the stars is their brightness, because the faint stars must, on the average, be more distant than the bright ones. Herschel then proposed to penetrate into space by means of a celestial census of the distributions and of the brightness of the stars. With this object he carried out four complete reviews of the heavens, as far as they may be seen from our latitude, passing successively to the fainter and fainter objects by means of the increased size of his telescope.

He divided the heavens into sweeps 2 degrees 15 minutes of breadth in declination, and each zone was examined throughout by the process which he called star-gaging. His census was made with the 20-foot reflector, with which instrument the field of view was about one-quarter of the size of the full moon. It needs over 300,000 of such fields of view to cover the whole of the hemisphere of space, and Herschel surveyed the whole northern hemisphere, and as much of the southern one as he could.

Herschel points out that by this survey he was not only looking into the most distant space, but also into the remotest past, for the light of many of the stars must have started on its journey toward us thousands or even millions of years ago. The celestial museum therefore exhibits to us the remotest past alongside with the present, and we have in this way the means of reconstructing to some extent the processes of evolution in the heavens. In photography the modern astronomer possesses an enormous advantage, but Herschel laid the foundation of this branch of astronomy without it.

The most conspicuous and the most wonderful object in the heavens is the Milky Way. It runs all round the skies in a great band, with a conspicuous rent in it forming a streamer which runs through many degrees. To the naked eye it shines with a milky light, but Herschel was able to show that it consists of countless stars in which there lie embedded many fleecy nebulæ. There is good reason to believe that the Milky Way on the whole consists of stars which are younger than those in the other parts of space, for the stars in it are whiter and hotter, and the nebulæ are mostly fleecy clouds. On the other hand, the spiral and planetary nebulæ are more frequent away from the Milky Way, and these are presumably older than the cloudy and flocculent nebulæ. The shape of the Milky Way seems to resemble a huge millstone or disk of stars, and since it forms a complete circuit in the heavens the sun must lie somewhere toward its middle. It is probable that we look much further out into space along this tract than elsewhere, although it happens that by far the nearest of all the stars—namely, α Centauri—lies in the line of the Milky Way.

This great congregation of stars is far from uniform in density, for there are places in it where there are but few stars or none at all. Caroline Herschel, writing to Sir John Herschel at the Cape of Good Hope, in 1833, mentions that her brother, when examining the constellation of the Scorpion (which lies at best low down on our horizon), had exclaimed, "after a long, awful silence, '*Hier ist wahrhaftig ein Loch im Himmel.*'" ("Why, there is a positive hole in the sky here.") And her nephew, as he said, rummaged Scorpio with the telescope and found many blank spaces without the smallest star.

It will explain some of the deductions which Herschel drew from his star-gages, and will at the same time furnish a good example of his style, if I quote a passage from a paper of his written in 1789.[1] He points out that the sun is merely a star, and, referring to the stars, he continues thus:

"These suns, every one of which is probably of as much consequence to a system of planets, satellites and comets, as our own sun, are now to be considered in their turn, as the minute parts of a proportionally greater whole. I need not repeat that by my analysis it appears that the heavens consist of regions where suns are gathered into separate systems, and that the catalogues I have given comprehend a list of such systems; but may we not hope that our knowledge will not stop short at the bare enumeration of phenomena capable of giving us so much instruction? Why should we be less inquisitive than the natural philosopher, who sometimes, even from an inconsiderable number of specimens of a plant, or an animal, is able to present us with the history of its rise, progress and decay? Let us then compare together, and class some of these numerous sidereal groups, that we may trace the operations of natural causes so far as we can perceive their agency. The most simple form, in which we can view a sidereal system, is that of being globular. This also, very favorably to our design, is that which has presented itself most frequently, and of which I have given the greatest collection.

"But, first of all, it will be necessary to explain what is our idea of a cluster of stars, and by what means we have obtained it. For an instance I shall take the phenomenon which presents itself in many clusters. It is that of a number of lucid spots, of equal luster, scattered over a circular space, in such a manner as to appear gradually more compressed toward the middle, and which compression, in the clusters to which I allude, is generally carried so far, as, by imperceptible degrees, to end in a luminous center of an irresolvable blaze of light. To solve this appearance it may be conjectured that stars of any given very unequal magnitudes may easily be so arranged, in scattered, much extended, irregular rows, as to produce the above described picture; or, that stars, scattered about almost promiscuously within the frustum of a given cone, may be assigned of such properly diversified magnitudes as also to form the same picture. But who, that is acquainted with the doctrine of chances, can seriously maintain such improbable conjectures?"

Later in the same paper he continues:

"Since then almost all the nebulæ and clusters of stars I have seen, the number of which is not less than three and twenty hundred, are more condensed and brighter in the middle; and since, from every form, it is now equally apparent that the central accumulation or brightness must be the result of central powers, we may venture to affirm that this theory is no longer an unfounded hypothesis, but is fully established on grounds which can not be overturned.

"Let us endeavor to make some use of this important view of the constructing cause, which can thus model sidereal systems. Perhaps, by placing before us the very extensive and varied collection of clusters and nebulæ furnished by my catalogues, we may be able to trace the progress of its operation in the great laboratory of the universe.

"If these clusters and nebulæ were all of the same shape, and had the same gradual condensation, we should make but little progress in this inquiry; but as we find so great a variety in their appearances, we shall be much sooner at a loss how to account for such various phenomena, than be in want of materials upon which to exercise our inquisitive endeavors.

. . . . . .

"Let us, then, continue to turn our view to the power which is molding the different assortments of stars into spherical clusters. Any force, that acts uninterruptedly, must produce effects proportional to the time of its action. Now, as it has been shown that the spherical figure of a cluster of stars is owing to central powers, it follows that those clusters which, *ceteris paribus*, are the most complete in this figure, must have been the longest exposed to the action of these causes. This will admit of various points of view. Suppose, for instance, that 5,000 stars had been once in a certain scattered situation, and that other 5,000 equal stars had been in the same situation, then that of the two clusters which had been longest exposed to the action of the modeling power, we suppose would be most condensed, and more advanced to the maturity of its figure. An obvious consequence that may be drawn from this consideration is that we are enabled to judge of the relative age, maturity or climax of a sidereal system, from the disposition of its component parts; and, making the degrees of brightness in nebulæ stand for the different accumulation of stars in clusters, the same conclusions will extend equally to them all. But we are not to conclude from what has been said that every spherical cluster is of an equal standing in regard to absolute duration, since one that is composed of a thousand stars only must certainly arrive to the perfection of its form sooner than another which takes in a range of a million. Youth and age are comparative expressions; and an oak of a certain age may be called very young, while a contemporary shrub is already on the verge of its decay. The method of judging with some assurance of the condition of any sidereal system may perhaps not improperly be drawn from the standard laid down earlier; so that, for instance, a cluster or nebula which is very gradually more compressed and bright toward the middle may be in the perfection of its growth, when another which approaches to the condition pointed out by a more equal compression, such as the nebulæ I have called *Planetary* seem to present us with, may be looked upon as very aged, and drawing on toward a period of change, or dissolution. This has been before surmised, when in a former paper I considered the uncommon degree of compression that must prevail in a nebula to give it a planetary aspect; but the argument which is now drawn from the powers that have collected the formerly scattered stars to the form we find they have assumed, must greatly corroborate that sentiment.

"This method of viewing the heavens seems to throw them into a new kind of light. They now are seen to resemble a luxuriant garden, which contains the greatest variety of productions, in different flourishing beds; and one advantage we may at least reap from it is, that we can, as it were, extend the range of our experience to an immense duration. For, to continue the simile I have borrowed from the vegetable kingdom, is it not almost the same thing, whether we live successively to witness the germination, blooming, foliage, fecundity, fading, withering and corruption of a plant, or whether a vast number of specimens, selected from every stage through which the plant passes in the course of its existence, be brought at once to our view?"

I now turn to another line of discovery which, to me at any rate, is more interesting. Until 1838—that is to say, until sixteen years after Herschel's death—no one had succeeded in determining the distance of a single fixed star, but in that year Henderson and Bessel almost simultaneously attained success in the cases of the two stars α Centauri and 61 Cygni. The attempts at this measurement had already been numerous, and Herschel among others had failed, but his failure was a glorious one, for he made incidentally a discovery of another kind and of at least equal interest.

The earth moves around the sun at a distance of 93 million miles, so that in six months we shift our position by 186 million miles. If, then, there are two stars of which one is relatively near to and the other far from the sun, but so situated as to appear to us very close together, the near one ought to shift its position relatively to the distant one in the course of each six months. The amount of this change of position, called by astronomers annual parallax, should furnish the distance of the nearer of the pair, provided that the other is very far off. This idea is as old as the time of Galileo, but no one had been able to make successful use of it.

As I have already said, the only general test of the distance of a star is its brightness, and therefore Herschel chose pairs of stars of very different brilliancy. He thought, at least at first, that it was mere chance which brought the stars so near to one another, and there are undoubtedly such pairs now known as "optically double stars." But Herschel's mode of attack was bound to fail if the seemingly neighboring stars were really so, and were linked together by their mutual gravitation. Already as early as 1707 Michel has suggested the existence of such true double stars, but it was Herschel who proved their existence. His first catalogues of double stars, published in 1782, contained 203 cases of such doublets, and he already suspected a community in their motions explicable only by their real association; but by 1802 he had become certain. In many cases the two components of a binary pair were found to be moving in nearly the same direction and at the same speed, but superposed on this motion of the system as a whole there was an orbital motion of one star round the other. Herschel even lived long enough to see some of his pairs of stars perform half a revolution about one another.

After his death Savary took the matter one stage further, and showed that the revolution was governed by the laws of gravity, and thereby confirmed the truth of Herschel's belief. Thus the failure to measure the distance of stars led to the proof that gravity reigns among the stars as in the solar system.

Arago thought that of all Herschel's discoveries this was the one that had the greatest future, and his prophecy has proved singularly correct. Every year adds to the

[1] *Phil. Trans.*, Vol. LXXIX, p. 212.

number of double stars, whose orbits are now accurately determinable. These systems are found to be very unlike our own solar system, for the component stars are, in many cases, far larger than the sun and revolve about one another in periods which, in various cases, may be either many years or only a few hours.

The spectroscope has, moreover, added enormously to our knowledge, for the speed of approach or recession of a star from the sun can now be determined as so many kilometers per second. Thus that component of the motion of a star which was concealed from Herschel is now known with the greater certainty. Moreover, being ignorant of the distance of the stars, he could only express the transverse component of motion in seconds of arc.

A wonderful corollary also results from the use of the spectroscope, namely, the existence of many stars known as "spectroscopic binaries." As seen even with the most powerful telescope such a star is a single point of light, but if the spectral lines are duplicated we know that the source of light is double, and that one component is approaching us and the other receding from us In this way the orbits and relative masses of these visually inseparable stars are determinable. The number of known double stars, including both visual and spectroscopic ones, is already large, and Campbell, of Lick Observatory, has expressed his opinion that one star in six is double. Some of them revolve so near to one another and in such a plane that they partially eclipse one another as they revolve, and thus produce a winking light like that of a lighthouse. It would seem that we can now even tell something of the shapes of a pair of stars visually inseparable from one another. But I must not go further into this subject, and will only repeat Arago's saying, that this discovery of Herschel's has "*le plus d'avenir*."

It is a figure of speech to refer to the stars as fixed, for a large number of them possess a measurable amount of "proper motion" relatively to their neighbors. The existence of double stars was discovered by the observation of their movements, and thus the study of proper motions is linked to the subject of which I have just been speaking. Some few proper motions had been observed by earlier astronomers, but when Herschel took up the subject proper motion had not been accurately measured in any case.

If a man is walking through a wood the trees in front of him seem to be opening out before him, while those behind seem to be closing together. In the same way if our sun is moving relatively to the center of gravity of all the stars, the stars must on the average seem to move away from the point toward which the sun is traveling, while they must close in toward its antipodes. These points are called the apex and antapex of the sun's path.

Now Herschel concluded that there was something systematic in the proper motions of the stars, and that there was a point in the constellation of Hercules from which the stars were on an average receding, and that similarly they were closing in toward the antipodal point. The first of these is the sun's apex and the second the antapex. These conclusions were drawn from the motions of comparatively few stars, but the result has been confirmed subsequently from a large number. Moreover, we have now learned by means of the spectroscope that we are traveling toward Hercules at the rate of about sixteen miles a second.

During the last few years this grand discovery of Herschel's has gained a great extension at the hands of Kapteyn and of many others, and it has been proved that other systematic motions of the stars are discoverable. The time at my disposal will not permit me to pursue this subject further, but I may say that it now appears that if we could view the universe from the center of gravity of the stars of the Milky Way, we should see a current of stars coming from a definite direction of space and penetrating our system.

Some Experiments on the Hydrolysis of Sawdust*

Sugar and Alcohol from Wood

By Wallace P. Cohoe

THE effect of acids upon cellulosic materials has engaged the attention of chemists since the time of Braconnet in 1819.

Simonsen was the first to attempt the manufacture of sugar from sawdust on any large scale. He used both sulphuric and hydrochloric acids of from 0.3 to 0.7 per cent strength in quantity under a pressure of seven to eight atmospheres.

In Classen's process fairly dry sawdust was treated with 2½ to 3 per cent of sulphurous acid, the amount of moisture present usually equalling the weight of dry sawdust. The digester was heated externally, and the excess of sulphurous acid was blown off and recovered. This process has been exploited, but cannot as yet be pronounced a commercial success. Though the yields of this method are very satisfactory, both in quantity and quality, yet the slowness of external heating seriously limits the output of a plant.

Reference should be made to the recent developments which have been made in Sweden in fermenting the sugars produced in the digestion of sulphite pulp. It is apparent that the hydrolysis of sawdust by sulphurous acid and acid sulphites, is making the production of alcohol possible on a commercial scale.

In Ewen and Tomlinson's method, which is being worked commercially in North America, sawdust is hydrolysed by sulphuric acid, the glucose produced being subsequently fermented. In this process conditions of moisture and percentage of acid approximate those of Classen, but the digester is heated internally by means of live steam.

Attracted by the fact that hydrochloric acid seemed to be more active than other acids in decomposing cellulosic materials, I was led to investigate the action of hydrochloric acid upon sawdusts under conditions where the reacting materials should be heated internally by live steam, and where the amount of water present should not exceed by more than 50 per cent the weight of dry sawdust in the digester.

Investigations on a commercial scale of methods not described in this paper are outlined in United States Patent (No. 985,726).

EXPERIMENTAL PART.

I.—Box factory sawdust of moderate fineness, and also sulphite pulp, was heated to 125 to 150 deg. Cent. in sealed tubes in an oil bath, with hydrochloric acid in varying proportions from ½ per cent to 3 per cent real hydrochloric acid calculated on the weight of dry sawdust. In order that the circulation of the reacting acid might be complete, the conditions of Simonsen as to moisture were found to be necessary. Various yields were obtained, ranging from 25 to 29 per cent of reducing sugars, calculated on the weight of dry wood originally present. It was found in a single reaction impossible to attain a much higher percentage of reducing sugars than 29 per cent, i. e., this hydrolytic reaction runs to an equilibrium.

By emptying the tube, washing out the sugars already formed, and repeating the process, it is possible with hydrochloric acid to obtain a further yield of reducing sugars, smaller in quantity, however, than the first yield. Thus, if in the first operation 29 per cent were obtained, in the second probably only 15 per cent of reducing sugars, calculated as above, could be obtained. This repetition can be made time and again, with gradually decreasing production of sugars. This reaction has not been taken beyond a conversion of 60 per cent of the weight of original dry sawdust present into reducing sugars, although if there were any economic possibilities no doubt nearly all the material could be so converted.

In this ability to convert material already acted upon, hydrochloric acid differs from sulphurous acid. Not only were we invariably unable to obtain as high a percentage of reducing sugars by using sulphurous acid, but we were also unable to obtain more than a 1 per cent or 2 per cent conversion on material already treated. When material already acted upon by sulphurous acid, was subjected to the action of hydrochloric acid, results comparable to those produced upon material correspondingly treated with hydrochloric acid were obtained.

II.—The next series of experiments was carried out on such a scale that a kilogramme of dry sawdust could be used, and the conditions made to approximate those which were desired finally. A small digester 8 inches in diameter, and 10 inches long, was made out of steel pipe and cast iron fittings. The plates at either end were fitted with a shaft, and the whole apparatus rotated on bearings, in an iron oil bath which was externally heated by gas. Provision was made in one of the heads of the digester for the admission of steam, and for the blowing off of the digester. The two heads of the digester were covered with sheets of asbestos paper impregnated with Bakelite, and pressed on in a hydraulic press. The interior of the digester was coated with a mixture of Bakelite and asbestos, and baked on without pressing.

In the first series of experiments the amount of water present was decreased until it was practically equal to the amount of dry sawdust present. The acid was introduced, and the digester closed and heated externally in the oil bath for one hour. The average yield obtained from this method was 25 per cent of reducing sugars calculated on the dry weight of sawdust introduced into the digester.

The first experiments were conducted with external heating. Next it was found that similar results could be obtained by the introduction of live steam into the interior of the digester, although unless the digester were also heated in the oil bath, considerable condensation took place, on account of the large area of radiating surface.

In view of the fact that the reducing sugars produced by this reaction did not all ferment, and also of the fact that the total amount of conversion was not by any means represented by reducing sugars, it occurred to the author that the presence of the hydrolysing agent during the heating stage might exert a harmful effect upon the final result. To overcome this the digester was filled and heated to the reacting temperatures, and then the reacting agent was introduced. This method is the one finally adopted.

III.—The apparatus next used comprised a digester capable of holding 800 to 900 pounds of ordinary saw dust, consisting of a steel plate shell with rounded ends provided with trunnions for purposes of rotation. The digester is provided with a manhole, by means of which it may be filled and emptied. The longitudinal pipe, made of special bronze, provides means for the admission of live steam, and also for the admission of the reacting agent, which may be introduced from the acid container, being forced against the steam pressure by compressed air. The length of the digester was 4 feet on the straight side, and the diameter was also 4 feet.

The lining of the digester had to be capable of resisting the action of diluto hydrochloric acid at high temperatures. First, the inside of the shell and ends were covered with a layer of asbestos paper which had been dipped in liquid Bakelite. Not having suitable acid-proof bricks, the interior lining was made of split firebrick. A paste of liquid Bakelite and barium sulphate was spread upon the lining, and the brick was embedded in this paste. When the whole interior had been lined in this way, a charcoal stove was introduced through the manhole and the interior heated slowly to harden the cement. A few gallons of liquid Bakelite was then introduced into the digester, the manhole closed, the digester rotated, and compressed air introduced. In this way all the bricks were thoroughly impregnated with the liquid Bakelite. The excess of Bakelite was removed, and a slow fire, as previously described, started in the interior, care being taken not to heat so suddenly that blistering took place. The temperature was gradually increased, and the lining was thoroughly baked. It has been found from more than a year's experience of almost constant work, that not only was this lining able to resist the action of 3 per cent hydrochloric acid solutions at a pressure of 150 pounds, with a corresponding steam temperature, but that it also resisted sulphuric and sulphurous acids equally well and at the same time, as far as can be judged, is intact. This is especially remarkable in view of the fact that it has been the practice to blow off the digester from the pressure attained by the reaction to atmospheric pressure, within a period of five minutes.

In the experiments various qualities of soft wood sawdust have been used, including fine box factory sawdust, containing 12 to 15 per cent of moisture; an ordinary fairly dry mill sawdust such as is obtained in Toronto; and mixed fine and coarse sawdust. For the most part the work was done with coarse sawdust containing from 40 to 60 per cent of water, such as would be met with under ordinary working conditions on a large scale.

In making a run the following procedure was followed: The digester is rotated into such a position that the manhole is on the top. The sawdust is introduced from above through a chute, the moisture content of the sawdust, of course, having been previously determined. The digester is then rotated, and at the same time live steam is blown in. The result is that in a short time, varying with the amount of moisture present in the sawdust, a pressure equal to the steam pressure used is attained. When this pressure is reached the digester may be blown off. In this way it is possible

* Reproduced from the *Journal of the Society of Chemical Industry.*

to recover any turpentine which may be present in the wood, any acetic acid which may be developed by the heat of the steam, any water in excess of that desired, and any volatile by-products which may be present. Among these latter it may be noted that a small percentage of furfurol is usually obtained in each digestion. In Canadian woods there is not enough turpentine present to be noticeable otherwise than by an oiliness on the top of the liquid condensed from the blow-off. After the blow-off the sawdust nearly always contains practically the same percentage of water, irrespective, within moderate limits, of the amount of water which was originally contained in the material.

After the pre-heating, the materials within the digester are in a condition most favorable for the hydrolysis. Steam is blown in, and then the reacting agent is introduced as rapidly as possible, and the digester rotated the necessary amount of time. The digester is then blown off as rapidly as possible, and the material dumped through the manhole.

The appearance of the material discharged from the digester varies with the percentage of acid used, the fineness of the sawdust, and the length of the digestion. Under the most favorable conditions where the best results are obtained, the material is a deep golden brown. The smell of furfurol is apparent in the blow-off vapors, also an odor suggestive of that accompanying the baking of cakes containing molasses.

For purposes of illustration a description of an early run may be interesting.

Run No. 6.—Previous to starting, the digester was heated by live steam, after which 800 pounds of sawdust containing 54 per cent of water was run in.

3:00 P.M. Started rotation and turned on steam.
3:05 " Steam gage pressure 20 pounds.
3:15 " " " " 40 pounds.
3:22 " " " " 50 pounds.
3:35 " " " " 90 pounds.
3:36 " " " " 95 pounds.
3:40 " Started to blow off.
4:10 " Blow-off completed.
4:15 " Started rotation, turned on steam.
4:22 " Gage pressure 50 pounds.
Blew in 28 pounds, 22 deg. B. hydrochloric acid.
4:30 " Steam pressure at 65 pounds.
5:25 " Stopped rotation, gage pressure 52 pounds. Blew off and dumped.
Percentage of sugar obtained, 16.62 per cent.

It will be seen from the above that in the early runs a very long time was taken, in fact, so long that no plant could afford to use such a process, as the output would be too small. Consequently progressive experiments were made to determine whether the process could be accelerated. The distributing tubes in the digester were modified so that instead of one central tube there were three, which distribute the acid and steam, not in the center, but about six inches from the circumference of the digester. In this way it is much easier to heat up the digester and its contents. It was also found that there was no special advantage in lengthening the time of the pre-heating; in fact, it was advantageous to make it as rapid as possible, especially in view of the fact that prolonged heating seems to render the material less readily attacked by the acid.

Illustrations of how the practice varied may be shown by run No. 136, in which the length of the pre-heating was reduced to 14 minutes, and the length of the digestion to 5 minutes. In this run, the results of which are shown in the table below, the percentage of acid used was essentially the same as in run No. 8, described above. In run No. 139 the time of the pre-heating was 12 minutes, and the time of the digestion 4 minutes. In run No. 140 the time of the pre-heating was 12 minutes, and the time of the digestion 3 minutes.

Given proper preparation of the materials by the pre-heating, and a proper adjustment of phases in the digestion, all the time necessary for a successful reaction is that required by a proper mixing of materials. In other words, with proper preparation the reaction itself is practically instantaneous.

Throughout all runs the observation made of results on the laboratory scale, with regard to the fact that this reaction runs to an equilibrium, was confirmed. It has been found by repeated experiments that by a proper adjustment of the phases, the concentration at which the equilibrium occurs may be varied.

The following table furnishes data obtained from various trials made during our experiments. The percentages are all in terms of analytical results, excepting the last column, which furnishes the ratio which the sugars bear to the non-sugars in the water-soluble extract from the digested material. As many of the runs enumerated in the table below were made under varying conditions, the results obtained are not comparable one with the other. The results of all analyses are calculated to the weight of dry material used.

No.	Unattacked.	Sugars.	Non-sugars.	Organic Acids, c.c. n/1.	Sugar, Per Cent. on Water-Soluble.
	per cent.	per cent.	per cent.		
72.....	71.9	16.6	11.5	51.5	59.1
76.....	67.8	12.6	19.6	92.8	39.2
83.....	76.1	15.6	8.4	27.2	65.0
87.....	71.6	16.8	11.6	39.1	59.2
90.....	73.9	15.1	11.0	31.4	58.0
94.....	75.4	15.7	8.9	39.4	63.9
97	75.0	16.5	8.5	36.0	66.0
117....	74.4	17.1	8.5	38.0	66.8
133....	73.2	17.4	9.4	59.4	64.9
134....	70.9	17.1	12.0	53.2	58.8
135....	71.0	18.0	11.0	71.4	62.0
136....	61.0	18.2	20.8	121.0	46.6
138....	69.7	17.4	12.9	62.7	57.4
139....	66.5	20.2	13.3	80.0	60.3

The value of the results obtained above, from a commercial standpoint, depends upon several factors, as follows:

A. *Extraction.*—If the sugars contained in the digested material are to be extracted for purposes of fermentation, or for the manufacture of refined glucose, the ease with which the soluble material may be extracted from the insoluble is a serious consideration. In such cases the coarse sawdust gives a much better result than the fine sawdust, as does also a conversion in the neighborhood of 18 per cent, rather than those yielding higher results. The greater the attack of the sawdust by acid, so much finer does the material become, and consequently so much harder is the extraction process. Also, the shorter the time of the conversion process, by so much is the grinding action of the particles on each other in the rotating digester reduced, and consequently the process of extraction is facilitated in corresponding proportion.

B. *Fermentation.*—Although most of the work has been done to determine what conditions promoted or hindered the conversion of sawdust into reducing sugars, yet the problem of determining how these reducing sugars can be converted into alcohol, has not been entirely neglected. In these experiments no particular attempt has been made to cultivate a yeast, either ordinary brewers' yeast or compressed yeast having been used in all cases. With a normal reaction, in which none of the phases are carried to an extreme, by the means mentioned above, it has been found possible to convert from 75 to 80 per cent of the reducing sugars present into alcohol. This ratio, while it is satisfactory, can probably be very much improved by the cultivation of a yeast which would work to better advantage in the extracted material from converted sawdust.

Several conclusions have been reached with regard to the reaction described above, which may be summarized as follows:

1. It is advantageous to have the sawdust heated to the reaction temperature before introducing the acid.
2. A prolonged pre-heating is not advantageous.
3. The recovery of valuable by-products, such as turpentine, is possible, using this method.
4. Coarse sawdust gives better result than fine.
5. By this method the time of conversion may be very much shortened over that consumed in existing methods, and consequently the output from a given plant may be very much increased.
6. Higher results have been obtained with hydrochloric acid than with other acids used by this method.
7. Commercial feasibility of the use of other acids.
8. Commercial advantage of double heating.

The problem of determining the identity of the reducing sugars and other water-soluble bodies produced by this conversion, is a most interesting one. Considerable time and attention has been devoted to it, but although certain conclusions have been reached, they have not been confirmed sufficiently to warrant a pronouncement on this subject as yet.

The Origin of Novæ

In the monthly notices of the Royal Astronomical Society for June, 1912, Prof. E. E. Barnard publishes a paper on "Micrometrical Measures and Focal Peculiarities of Nova Lacertæ." He takes occasion to criticise some of the theories concerning novæ that have been accepted by some astronomers.

"The assumption that the outburst is due to a star colliding with a nebula is one of these. From what we know of the nebulæ in general they are very diffused masses of gaseous matter whose limits in many cases are uncertain because of their diffusion and faintness. I reject from this criticism the planetary nebulæ which are very definite in outline, but we must also reject these from the theory because of their relative smallness and scarcity. The enormous quantity of nebulous matter shown to exist in space, makes it not only possible but probable that stars may sometimes run into it. The main point that seems unreasonable is that such an encounter with a nebula should produce the sudden outburst of light. Because of the diffused and attenuated condition of the outlying portions of the nebula it seems more reasonable that the increase of light by friction should be gradual and occupy years, instead of a few hours as actually occurs in the case of the Novæ, or, in other words, the star should slowly brighten just as a meteor (relatively speaking) does in our own atmosphere. Such an encounter with a nebula would be a matter of many years of disturbance in the light of the star, and in the case of a more or less central encounter with a large nebula, a matter of ages.

"The theory that the Novæ are produced by the sudden rush of a star into a nebula is unreasonable and should be rejected. Photography does not show that the Novæ are in nebulous regions except in the case of Nova Andromedæ, and even here the spectroscope throws doubt upon the nebulosity. One would rather accept the theory of the collision of one star with another, but this theory does not appeal to me. It would seem more reasonable that the outburst of light is produced by some sudden change in the star's physical condition by forces inherent in the star itself, and that no outside influence enters into the problem.

"One explanation of the apparently moving waves of nebulosity that were shown by photography to be receding from Nova Persei of 1901, and which seems to have been received with much favor, is that the star was in a large nebula when the outburst occurred, and that the apparent recession of this matter from the Nova was simply due to the progressive motion of the light successively illuminating structural portions of the nebula as the light receded from the star, and not a motion of the matter itself.

"This explanation seems to have been generally accepted and the parallax of the star fixed, from this theory, at 0″.01. Not only this, but this more than questionable value has been freely used in connection with other problems in astronomy. In reality it would seem that we know nothing of the actual distance of Nova Persei. I cannot see how anyone can still hold this theory after having examined the photographs made by Ritchey and Perrine with the reflectors of the Yerkes and Lick observatories, for the individual details are clearly shown on the successive photographs to be moving outward bodily from the star. It is asking too much to claim that these are not identical structures which are shown in the various photographs.

"If those who have not examined the evidence given by the photographs will turn to Plates XVIII. and XIX. in the *Astrophysical Journal*, Vol. XIV., and carefully compare the two plates taken by Ritchey with the two-foot reflector of the Yerkes observatory, they will, I think, readily verify the following facts. The sharp-pointed projection marked *a* in Plate XIX., Fig. 2, 1901, November 13th, has moved outward bodily when compared with Fig. 2, Plate XVIII., 1901, October 20th. Other details of the nebulosity also unquestionably show that there is actual outward motion of the nebulosity. This is specially noticeable in the case of the small tuft just free of the edge of the nebula at *b*, also in the case of the region of *f*, and at other points. Of course in the interval of twenty-four days some changes have necessarily taken place in some of the details of the nebulosity, but allowing for this, essentially all the details in the two drawings can be reconciled. This progressive motion of individual details is even better shown in Plates VI., VII., VIII., IX., X., of Vol. XV. of the *Astrophysical Journal*, where Mr. Ritchey has given additional pictures of the star and the receding nebulous features. To those who do not have access to the *Astrophysical Journal*, the motion of *a* is well shown in the two photographs reproduced in 'The Heavens and Their Story,' by Mr. and Mrs. Maunder, Plate LIX.

"I am aware that this theory of the successive illumination of the nebulous matter by the outgoing light from the star was forced upon astronomers by the enormous velocity that had to be accounted for if the masses were in real motion. Though the light and nebula theory might conveniently explain the motion, it is directly antagonistic to the facts and should be rejected. What we have to deal with in this case is probably real motion caused by some force not yet known. Indeed, I think this, like some of the abnormal phenomena of the comets, reveals to us the effects of new forces (call them that if you like) as yet unknown to us, but which we must take into consideration as our knowledge of the universe advances."

The Vibrations of Telephone Diaphragms*

An Experimental Investigation

By Charles F. Meyer and J. B. Whitehead

HISTORY.

INVESTIGATIONS of the vibrations of telephone diaphragms have been published by Rayleigh,[1] Wien,[2] Kempf-Hartmann,[3] Taylor,[4] Gati,[5] and others. Rayleigh and Wien measured the value of the simple harmonic current which would just produce an audible tone in the receiver at different frequencies. They found that at certain frequencies the current required was a minimum, and Wien concluded that these minima showed the existence of natural vibrations of the diaphragm, but realized that the variation in sensibility of the ear with pitch played possibly a larger part in the difference of current required at different frequencies than the natural vibrations themselves.

Kempf-Hartmann fastened a mirror on the diaphragm of a receiver and photographed on a moving film the oscillations of a spot of light reflected from the mirror. By passing direct current interrupted about 100 times per second through the telephone he was able to photograph the natural oscillations of the diaphragm which were produced at each make and break, and showed also that when the diaphragm had been given an impulse its reaction could be detected after about 1/2000 of a second.

Taylor has plotted curves showing the connection between the least current producing an audible tone and the frequency, his work being similar to that of Rayleigh and Wien. He noticed that as the alternating current generator from which he obtained his current accelerated or slowed down there were certain frequencies at which the sound from the receiver was very

Fig. 1.—Cap of Receiver—the Shaded Portion was Cut Away.

much increased, and he plotted rough curves showing this.

Gati has worked with transmitters. He produced before the diaphragm a sound of which the frequency

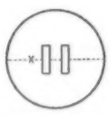


Fig. 2.—The *X* Marks the Position of the Mirror on the Diaphragm.

was varied, but the amplitude was kept as constant as possible. The transmitter was in circuit with a battery and the primary of a transforming coil. To the secondary of the coil he connected the capacity required to produce electric resonance at each frequency and measured the current in the secondary circuit. Plotting curves between frequency and current a decided maximum is obtained showing resonance at about 700 vibrations per second.

The mathematical theory of the free oscillations of circular membranes and plates has been developed. It shows that the nodes are either circles about the center, or diameters symmetrically distributed,[6] this holding true for plates with either a free or a clamped boundary; the boundary of membranes is, of course, necessarily fixed. Rayleigh gives the following formula for the frequency of the lowest natural vibration of a clamped plate.

$$n = \frac{3.2^2 \sqrt{q\,h}}{2\,\pi\,a^2 \sqrt{3\,\rho\,(1-\mu^2)}}$$

where q = Young's modulus.
μ = Poisson's ratio.
ρ = volume density.
$2h$ = thickness of plate.
a = radius of plate.

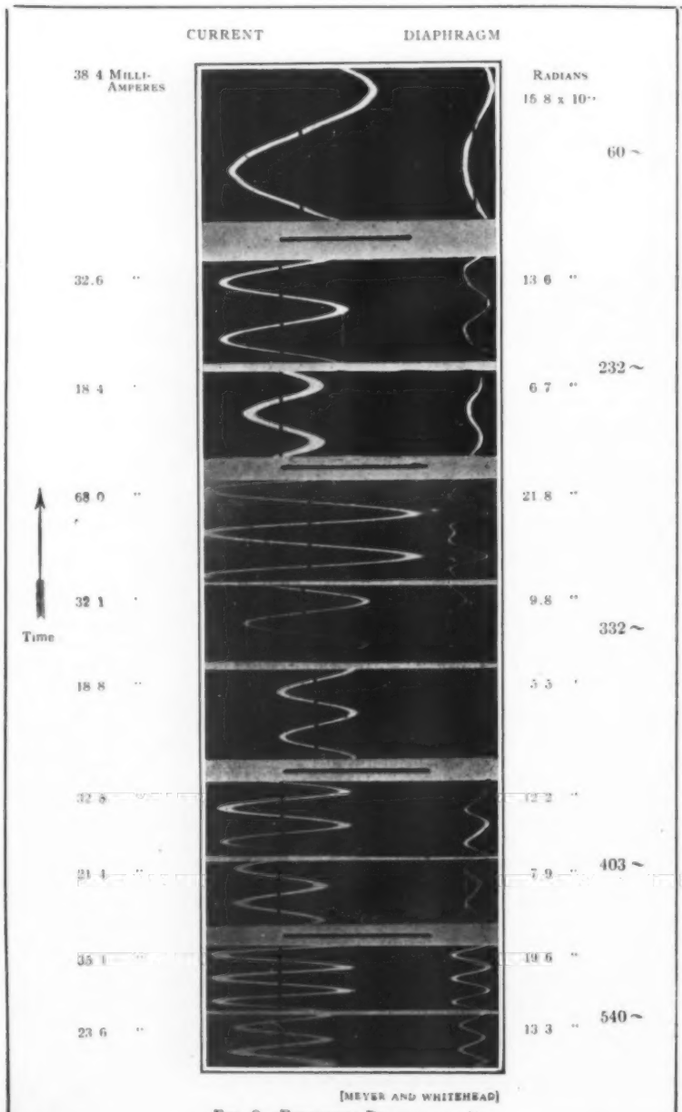
He applies the formula to the case of a receiver diaphragm which he measured and found 991 as the fundamental frequency. No experimental verification of this seems to have been attempted.

OBJECT.

The present work was undertaken to obtain further and more accurate information concerning the way in which the diaphragms in the transmitter and receiver vibrate when acted on by periodic forces of simple wave

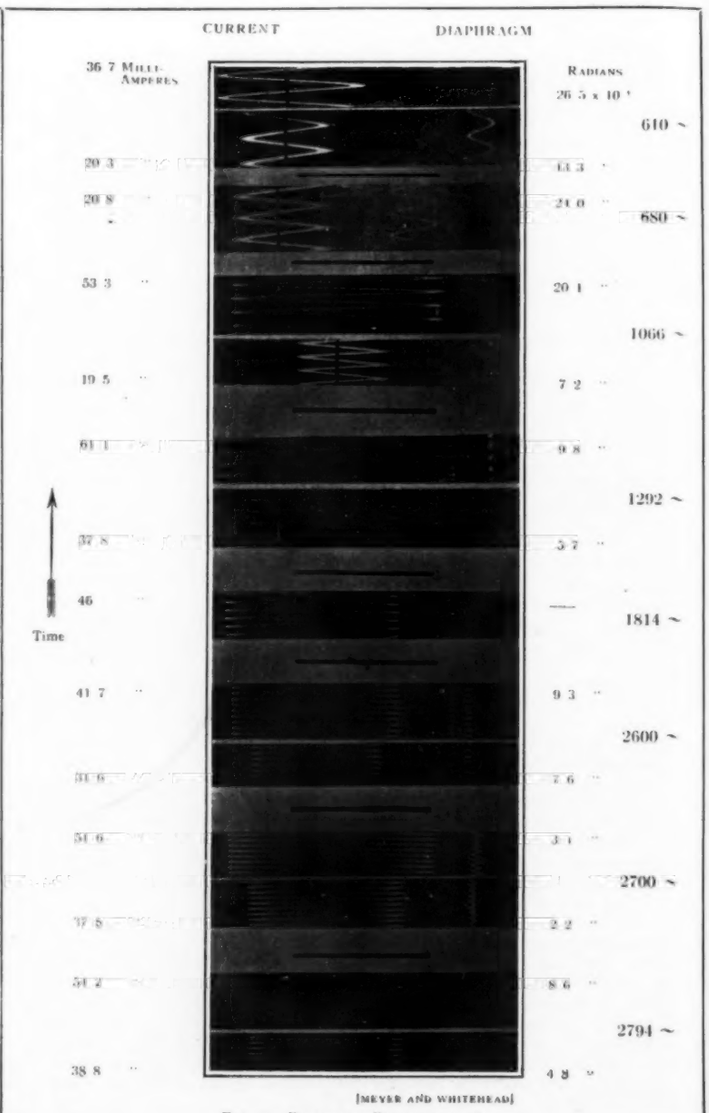
* A paper to be presented at the twenty-ninth annual convention of the American Institute of Electrical Engineers, Boston, Mass., and published in the *Proceedings* of the Institute.

[1] Rayleigh. "Theory of Sound," I, p. 473.
[2] Wien. *Annalen d. Phys.*, IV, p. 430, 1901.
[3] Kempf-Hartmann. *Annalen d. Phys.*, VIII, p. 481, 1902.
[4] Taylor. *Proceedings* A. I. E. E., XXVIII, 1184, 1909.
[5] Gati. *Electrician*, LXVI, p. 456, 1910.
[6] Rayleigh. "Theory of Sound," Vol. I, pp. 331, 366.



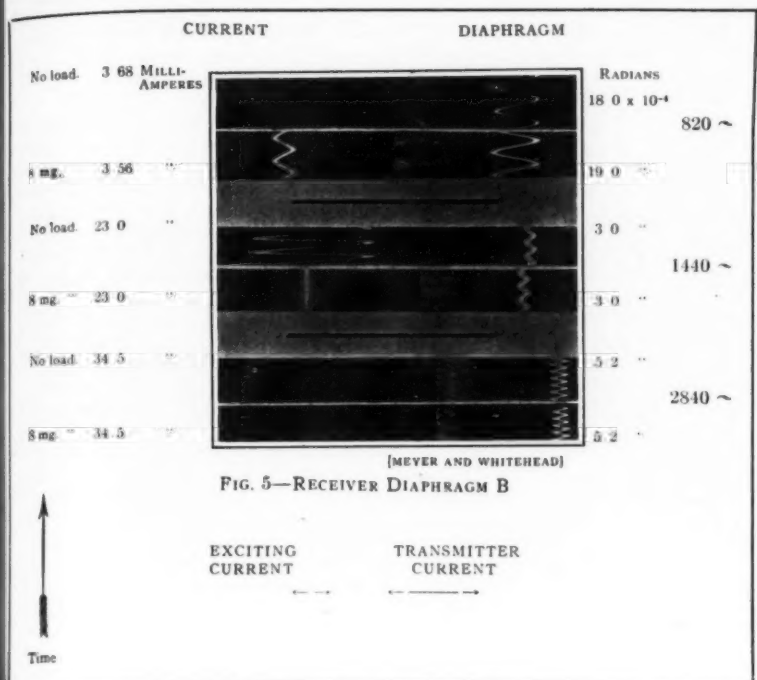
[MEYER AND WHITEHEAD]

FIG. 3—RECEIVER DIAPHRAGM A



[MEYER AND WHITEHEAD]

FIG 4—RECEIVER DIAPHRAGM A



[MEYER AND WHITEHEAD]

FIG. 5—RECEIVER DIAPHRAGM B

[MEYER AND WHITEHEAD]

FIG. 6—TRANSMITTER

form of different frequencies. Also to obtain quantitative data on the influence of the free periods, and to determine to what degree of approximation the form of the vibration of the diaphragm follows that of the impressed force. The question of the localization of the nodes and loops at the higher resonance frequencies is also interesting, but it has thus far evaded solution.

WORK ON THE RECEIVER.

Arrangements and Apparatus.—The receiver is simpler in construction than the transmitter and is, therefore, more easily investigated. With the receiver the problem is to pass through it an alternating current of simple wave form, as nearly simple harmonic as obtainable, and to record the form of the current, and the corresponding oscillation of the diaphragm. The amplitude of the oscillation of the diaphragm for the same current at different frequencies, plotted against frequency would then give the resonance curve for the diaphragm. For producing the alternating currents two special generators with smooth body armatures were used for low frequencies. For the principal range a third generator was used With these three machines frequencies from 16~ to 3000~ could be attained. The current wave form was recorded by a Duddell double high frequency oscillograph, used simultaneously as oscillograph and ammeter. An oscillograph of this type has a free period of from 8,000 to 10,000. It may hardly be relied upon to record with any accuracy a wave of over three or four hundred cycles. In the present case, however, the current wave is, with a few exceptions, very nearly pure, and the question of wave form does not enter markedly into the results of the work.

The method adopted for recording the oscillations of the diaphragm was as follows: A small fragment of mirror was mounted directly on the diaphragm by means of wax or cement, and its vibrations recorded by a spot of light reflected upon a photographic plate. It is easy to mount the mirror rigidly, and its mass which may be 0.007 of a gramme or under, is too small to influence the motion of the diaphragm greatly. There can further be no doubt that the angular deviation of the mirror is the angular deviation of the diaphragm, at the point where it is mounted.

DIAPHRAGM A.

The first receiver worked with was one of the ordinary bipolar type. Its characteristics were: Total diameter of diaphragm 5.42 centimeters (2.14 inches). Inside diameter of clamping ring in cap, 4.98 centimeters (1.96 inch), this being the effective diameter of the diaphragm. Thickness of diaphragm with enamel on front fact 0.03 centimeter (0.012 inch). Thickness bare at edge 0.023 centimeter (0.009 inch). Distance between pole pieces and plane of clamping ring of diaphragm 0.05 centimeter (0.02 inch). The air gap between pole pieces and diaphragm is less than this as the diaphragm is permanently bent inward by the attraction of the magnet. The part of the cap extending over the diaphragm was cut out in order to make room for the small mirror which was fastened on. (See Fig. 1.) The mirror was placed about half way between the center and edge. The diaphragm was so oriented over the pole pieces that the mirror came on the perpendicular bisector as shown in Fig. 2. The receiver was then set up so that the mirror came on a horizontal diameter. Pulling in of the diaphragm corresponded to a motion to the right of the light spot on the photographic plate.

Some of the photographs obtained for this diaphragm are shown in Figs. 3 and 4, with frequencies noted for each set. The curves on the left are the oscillograph records of the current through the receiver, the number at the side giving its value in milliamperes (effective), calculated from a knowledge of the sensibility of the oscillograph. The curves on the right are the traces from the diaphragm, the accompanying figures giving the value of the angular deflection in radians $\times 10^{-4}$, calculated from the dimensions of the optical system. As these latter curves are unsymmetrical it is impossible to speak of their amplitudes, so the total deflection from one extremity of swing to the other is given; this quantity will henceforth be referred to as the "range" of the oscillation. The numbers on the extreme right-hand side of the figure give the frequencies of the vibration in cycles per second. In all of the photographs time proceeds upwards, as shown by the arrow. In the first traces a break is noticeable about the middle of the vibration, which indicates the rest positions of the spots of light. This break was produced by placing a fine wire in the path of the beam of light when there was no current, but wire was soon abolished as it introduced unnecessary complications.

The diaphragm trace for 60 cycles is seen to be somewhat unsymmetrical the curve being pointed on the right, that is, when the diaphragm is nearest the pole pieces. At 232 cycles for a range of 13.6 the curve is rather unsymmetrical, but for a range of 6.7 the irregularity is less marked. At 332~, and 1292~ also, the

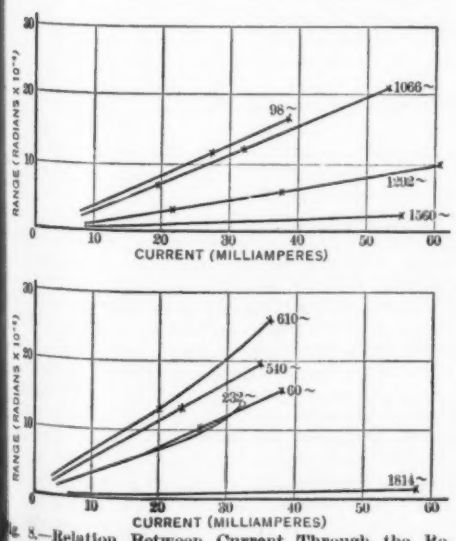
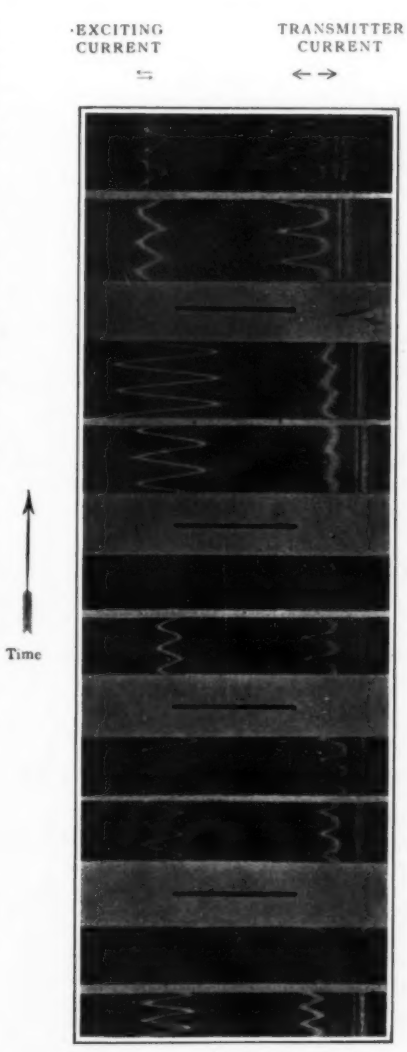


Fig. 8.—Relation Between Current Through the Receiver, and Range of Oscillations of the Diaphragm at Different Frequencies.



[MEYER AND WHITEHEAD]

FIG. 7—TRANSMITTER

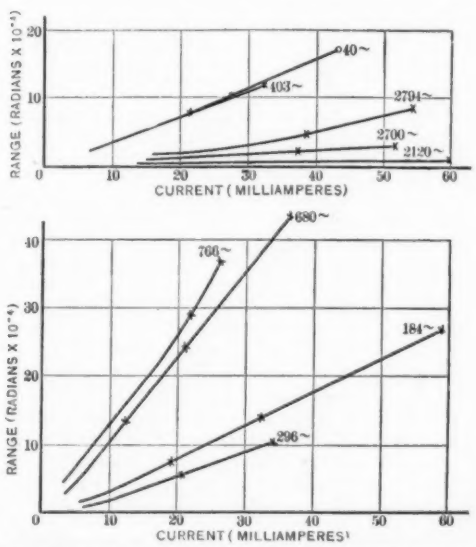


Fig. 9.—Relation Between Current Through the Receiver and Range of Oscillation of the Diaphragm at Different Frequencies.

irregularities are seen to be greater for greater ranges while for most of the other curves this is not noticeable. The development of the dimple in the curve for 332 and 1292~ at the point where the diaphragm is furthest from the poles is rather surprising; it will be seen later that 332~ shows a peculiarity in another respect. It might be expected from the following considerations to find greater regularity in the photographs for small ranges.

The force on the diaphragm is proportional to the square of the induction. If we consider the induction B as made up of a constant part B_0 due to the permanent magnetism, and a variable part B_1, due to the current, we have for the original force

$$F_0 = c\,B_0^2$$

and for the variable force

$$F = c\,B^2 = c\,[B_0^2 + 2B_0B_1 + B_1^2] \qquad (2)$$

The increment of the variable force over the original force determines the motion of the diaphragm. Its value is

$$\triangle F = F - F_0 = c\,[2B_0B_1 + B_1^2]$$

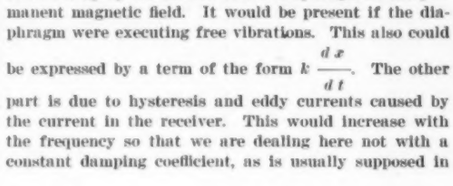
If B_1 is sufficiently small we may neglect its square and write

$$\triangle F = 2c\,B_0\,B_1 \qquad (3)$$

So that, if B_1 is made to vary harmonically, $\triangle F$ will do so. In the present work the currents have been kept nearly harmonic in all cases. The variation in the air gap between the pole pieces and the diaphragm, would prevent B_1 from being strictly proportional to the current, but for sufficiently small vibrations the influence of the variation in the air gap may be neglected.

The ranges of all the traces were carefully measured. The results obtained for the first diaphragm are plotted in the curves of Figs. 8, 9, and 10. The abscissæ are current through the receiver, expressed in milliamperes (effective). The ordinates are the angular range of oscillation of the diaphragm, expressed in radians $\times 10^{-4}$. Each curve gives the relation between current through the receiver and oscillation of the diaphragm at a given frequency which is marked beside it. The curves are all plotted to the same scale and put in separate figures to avoid crowding. They show that an approximately linear relation exists between the current and deflection of the diaphragm, even to the large values of current here used. The sound of the telephone for the greater currents was sufficient to be heard all over the room.

From each of the curves of Figs. 8, 9, and 10, the angular oscillation corresponding to a current of twenty milliamperes, at the frequency for which the curve is taken, can be read off. In Fig. 11 a curve is plotted between the frequency as abscissa, and the angular oscillation as ordinate, showing the effect of change of frequency on the angle of oscillation, this being the so-called resonance curve for the diaphragm. It will be noticed that the curve starts out horizontally, then drops to a minimum at 300~ from which it rises and reaches a maximum at 720~, at which the range of oscillations is about five times that of the minimum, and about four times that at the lowest frequency. After 720~ there is no other maximum until 2600~, and then shortly after this there appears to be another, but this was not quite reached as it was not desired to overspeed the machine at the time these records were obtained. It is rather surprising to find the minimum at 300, before the first maximum. At first its real existence was doubted but the appearance of a similar dip in the curve for the next diaphragm, with an entirely different make of receiver, seems to indicate a real effect. It should be remembered that the damping of the diaphragm in a receiver is not purely mechanical, but is partly electromagnetic, and this may have a bearing here. The mechanical effect can be expressed by a term of the usual form $k\,\frac{dx}{dt}$ in the differential equation of motion of the diaphragm. The electromagnetic damping we may consider to be made up of two parts. One of these is due to eddy currents set up by the motion of the diaphragm in the permanent magnetic field. It would be present if the diaphragm were executing free vibrations. This also could be expressed by a term of the form $k\,\frac{dx}{dt}$. The other part is due to hysteresis and eddy currents caused by the current in the receiver. This would increase with the frequency so that we are dealing here not with a constant damping coefficient, as is usually supposed in



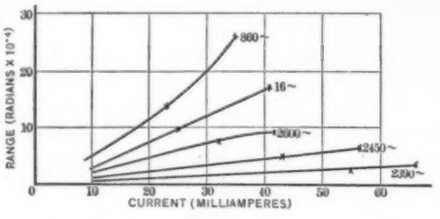


Fig. 10.—Relation Between Current Through the Receiver, and Range of Oscillation of the Diaphragm at Different Frequencies.

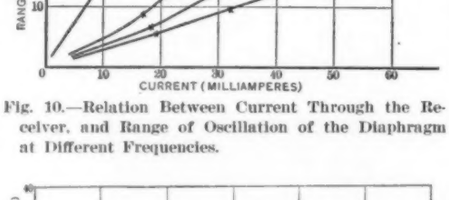


Fig. 11.—Resonance Curve for Diaphragm A. Giving The Relation Between Frequency and Range of Oscillating for a Constant Current.

the treatment of forced oscillations, but with one that increases with frequency. The minimum in the resonance curve appears at about 300~ and it is the trace at 332~ to which attention was called above, which shows the dimple. The plate for 296~ (not reproduced) was exposed in two sections giving traces very similar to the lower two of 332~. This plate was obtained before the one for 332~ and the range was not carried high enough to get the dimple. It cannot be definitely said that the minimum of the curve of the dimple in the trace are casually connected, but the coincidence is rather striking.

The resonance curve Fig. 11 covers the range of the important frequencies existing in the human voice. The lowest tone reached by man in singing is about 67 vibrations per second. The highest reached by a woman is 1036, but this tone contains harmonics of higher frequencies. A number of investigations have been performed on the vibrations contained in vowel sounds. According to results obtained by Bevier[1] the prominent frequencies are:

For *a* as in *hat*.....	650	1050	1550
" *e* " " *pet*.....	620	1050	1800
" *i* " " *pit*.....	575	1850	
" *i* " " *pique*.....			2050

In the consonants, especially those of the hissing type, very much higher frequencies exist, going in some cases as high as 10,000. These consonants have not the importance in speech that the vowels have, and it may well be said that the prominent vibrations are included between 300 and 3,000, probably not many lying above 2,000.

We may obtain a comparison between the fundamental frequency of the diaphragm determined experimentally, with that to be expected from Rayleigh's formula. The greatest ordinate of the resonance curve comes at 720. This ordinate for any system lies at a somewhat less frequency than its free vibrations. Further the actual frequency is somewhat less than it would be if there were no damping. It is this last value which is given by Rayleigh's formula. By applying the theory of a system with one degree of freedom to the resonance curve of Fig. 11, a simple calculation shows that if there were no damping the free frequency of diaphragm "A" would be 732. This is 12 vibrations a second higher than the point for the maximum ordinate of the curve. The difference is not greater than the error in measuring the frequency. Let us now substitute in equation (1). We may take

$$q = 2.0 \times 10^{12}$$
$$\mu = \tfrac{1}{4}$$
$$\rho = 7.7$$

which gives

$$n = 2.41 \times 10^5 \times \frac{2h}{a^2};$$

from the measurements of the present diaphragm,

$$2h = 0.023 \text{ centimeter.}$$
$$a = 2.5 \text{ centimeter.}$$

hence

$$n = 890.$$

this being the value required by Rayleigh's formula, whereas the value obtained experimentally is 732. The agreement is not very good, but a better result is hardly to be expected. The diaphragm has 0.007 centimeter (0.003 inch) of enamel on its front face, which probably loads it down without adding much to its stiffness, thus causing the actual value of the free frequency to be lower than the calculated one. The measurement of the thickness of the diaphragm is not very accurate, only a small spot on the edge being available for this, and moreover the value of Young's modulus substituted in the equation may not be the correct one for the iron of the diaphragm. It cannot be told in what direction more accurate values for these last two quantities would change the result.

To be continued.

[1] *Phys. Rev.*, 1901, 1902, 1903. Quoted by Barton "Text-book of Sound," p. 672.

Experimental Research in Aeronautics*

Report of a Year's Work at the National Physical Laboratory, England

Experiments on Airship Models.—During the past year further experiments have been made on the resistance of airship models, and on the forces and moments acting on inclined models of different forms. The resistance measurements included some tests of special shapes, made at the request of the superintendent of the Royal Aircraft Factory; and an investigation to determine the effect of bluntness of tail on the relative air flow and on the resistance. From visual observations and photographs of the flow past models in the small water channel, made with the aid of colored streams, it was noted that the flow in the tail region even of an elongated model was very slow. It was inferred that truncation or modification of the tail within this "dead" region should have little effect on the head resistance. A model was accordingly made in which successive sections of the tail were removable, and it was found, as expected, that the effect of the removal of portions of the tail within the "dead" region was negligibly small. In the model tested, the full length of tail was about twice the maximum diameter, and it was found that a length of 0.8 of the diameter, from the tip, could be removed without appreciable effect on the head resistance. It follows, therefore, that within this region the tail may be rounded off or otherwise modified without loss of speed; a gain in lifting power is thereby secured, while the less pointed form presents advantages from the constructional point of view.

In addition to the model experiments above described, an interesting series of determinations of the head resistance of eight different airship forms was carried out at the Royal Aircraft Factory. These models were made of goldbeaters' skin, and were about 18 feet in length, and 3 feet in diameter. The method employed was to tow the models horizontally through the air at different velocities, the speed being maintained by means of a falling weight. The conclusions arrived at from these experiments were generally in accordance with those deduced from the measurements made on small models of the same forms in the water channel at the National Physical Laboratory. From the point of view of total balloon resistance alone, a fineness ratio, or ratio of length to maximum diameter, of 6½ to 1 was found to be most efficient; but taking into account the other resistances of the completed airship, it was concluded that it might be desirable to reduce the fineness ratio to about 5¼ to 1.

The difficulties of obtaining results of high accuracy by the method of towing light models of this character through the air are very great, but nevertheless a comparison of the measurements of head resistance that made on models of 3 feet diameter, with those given by tests in water of ebonite models of 1 inch diameter, is of much interest. The difference between the densities of the two media, air and water, is not a source of difficulty in such comparison: the relative resistances are directly

* From the report of the Advisory Committee for Aeronautics for the year 1911–'12 (London: Wyman & Sons, Ltd.) Extracts reproduced from *Nature*.

proportional to the densities of the media, and allowance for the difference in density is thus readily made. According to the law of dynamical similarity, referred to in previous reports, and clearly enunciated by Lord Rayleigh in the report for 1909-10, the quantities on which variation in the resistance coefficient may be expected to depend are the relative dimensions, the relative velocities, and the "kinematical viscosities." The velocities in the two sets of experiments, made at the Aircraft Factory and the National Physical Laboratory, respectively, were 20 feet per second and 1.78 feet per second. The kinematical viscosities of air and water are in the ratio of 13 to 1. Employing the law of dynamical similarity the two series of experimental determinations enable a provisional estimate to be formed of the effect on the coefficient of head resistance of change in velocity, and of change in dimensions. Mr. Bairstow, of the National Physical Laboratory, has made the calculation, and employing the data so obtained, has estimated the resistance of a full-sized balloon, with smooth surface, of 40 feet diameter and of specified form, with fineness ratio of 6.1, when traveling at the rate of 40 miles per hour, to be 320 pounds weight.

To obtain further information on this important question of the variation of the resistance coefficient with dimensions, a large wooden model of an airship, 6 feet in length and 1 foot in diameter, has been made at the laboratory, and its resistance will be determined by towing tests in the William Froude National Tank. These experiments are now in progress. A further model, 4 inches in diameter and 2 feet long, is also under construction for towing tests in the tank, and it is hoped that a comparison of the various experimental results available may lead to valuable conclusions as to the relation between the resistance of models and of the full-scale machines, and may furnish data sufficient to enable the prediction, from observations on models, of the absolute magnitudes of the forces acting on full-sized airships and aeroplanes to be made with more confidence than is at present possible.

Investigation of the Pressure Distribution Round a Thin Plate and an Aerofoil.—The object of these experiment was to examine closely the character of the air flow round a thin plate or an aerofoil, and to investigate the way in which the total "lift" and "drift"—apart from friction—on the whole plate are built up from the pressures, or "suctions," at different regions of the upper and lower surfaces.

The detailed results and distribution curves, which will be given in the Technical Report, exhibit many points of interest, and of importance in aeroplane design. Thus for the aerofoil tested there was a particular angle at which the upper, convex surface gave its maximum contribution toward the total lift, and another, different angle at which the under, concave surface gave the maximum effect. It thus appeared to be a possibility that by variation of one of the surfaces improved efficiency could be obtained.

The nature of the pressure distribution on the convex surface of the aerofoil presents some remarkable features. At inclinations commonly occurring in flight practice, from 5 to 10 degrees, the negative pressure on the convex surface is a maximum, and reaches a very high value, at a point immediately behind the leading edge of the "plane." The same fact is shown in the distribution curves for different aerofoils at an angle of 6 degrees given by M. Eiffel, who has also carried out a large number of experiments in the plotting of pressure distribution, to which the National Physical Laboratory measurements may be regarded as complementary.

Another interesting feature of the results obtained for the aerofoil is that at an inclination of about 12½ degrees there is a marked change in the pressure intensity on the convex surface, and from 12½ to 20 degrees the conditions of flow appear to be so unsteady that no readings of the pressure intensity could be made, the pressure varying incessantly and erratically within wide limits. This critical region is also indicated, in a less marked manner, by the measurements made on the concave surface.

Effect of Separate Variation of the Upper and Lower Surfaces of an Aerofoil.—In continuation of the investigation above described, into the pressure distribution, the effect has been examined of varying one surface only of the aerofoil, the curved under surface of the aforementioned aerofoil being replaced by a plane.

The general conclusion arrived at is that, as a first approximation, each of the surfaces of an aerofoil can be independently designed; the second approximation, due to interaction between one surface and the other, is sufficiently small to be regarded as of the nature of a correction.

The curves obtained for the lift and drift, and the ratio of lift to drift, show clearly the effect of replacing a cambered under surface by a plane one. Over the useful range of inclinations from 7 to 12 degrees, the ratio of lift to drift is nearly the same for both aerofoils, but the lift coefficient at 10 degrees decreases from 0.48 to 0.42. It follows from this that about 14 per cent increase in wing area would be required to produce the same lift.

Effect of Variation of the Spacing of the Two Planes in a Biplane.—These experiments were made with two facsimiles of a wing form of the Blériot type, and the "gap" between the two planes was varied from 0.4 to 1.6 times the breadth of either plane. The results were corrected for the resistance of connections. They show appreciable loss of lift per unit area as compared with the single plane; when the "gap" is equal to the breadth of either plane, the loss is 17 per cent. Even with a "gap" equal to 1.6 times the breadth, the loss is still as much as 10 per cent. The "drift" values for the biplane do not differ greatly from those for the single plane; the percentage losses in the ratio of lift to drift are thus nearly of the same magnitude as those in the lift.

The advantage that might be gained by employing a wider spacing than the usual one, with a gap equal to or slightly greater than the breadth of a plane, is, of course, to some extent, counterbalanced by the increased resistance and added weight due to the extra length of struts necessary. The best spacing depends on the conditions of design, and is different if the speed be required to be kept constant from that most suitable for a machine having wings of fixed area. For flight speeds ranging from 40 to 60 miles an hour the best biplane spacing is in the neighborhood of that most commonly adopted, with a "gap" approximately equal to the chord.

Effect of Camber.—The effect of variation of the camber of the upper surface, and also of the lower surface, has been investigated. As already stated, it had been previously shown that, to a first approximation, the upper and lower surfaces might be independently designed. The experiments on the variation of camber of the upper surfaces were made on aerofoils having their lower surfaces plane. The amount of camber of the upper surface giving a maximum value of the ratio of lift to drift was found to be about 1 in 20, as compared with Eiffel's value of 1 in 13.5.

The experiments on the effect of varying the camber of the lower surface were made on an aerofoil in which the camber of the upper surface was about 1 in 10. It was found that the ratios of lift to drift were practically unaltered by the change of camber in the lower surface, but the lift coefficient at a given angle of incidence increased steadily with increase of camber, the gain in lift amounting to about 17 per cent for a lower surface camber of 1 in 16, as compared with a plane under surface.

Other Experiments in Connection with Aeroplanes.—Mr. O'Gorman has placed before the committee a considerable programme of further experimental work on aeroplane models, in relation to questions which have arisen in connection with constructional work proceeding at Farnborough. A scheme for further work has been approved by the committee, and this will be proceeded with as rapidly as circumstances permit. The committee held that the necessity of advancing more rapidly with these experiments rendered imperative the provision of another air channel; and, as already stated, it has been arranged to build a channel of section 6½ feet square, for which provision will be made by the treasury. The increased accuracy in measurement which it is hoped to attain by improved design in the reconstruction of the 4-foot channel will also, if realized, appreciably increase the rate at which experimental data can be obtained.

Effect of Blade Area and Pitch on Propeller Efficiency.—At a constant translational speed, the departure from maximum efficiency is negligibly small over a fair range of blade widths, from about 3.4 to 4.8 inches. The change of thrust under the same conditions is also small.

Tests have also been made on two series of propellers of different blade widths, in which the pitch was varied somewhat on either side of that obtaining in the original design. Some effects of increase in pitch may be inferred from these experiments; with the wider blades an improvement in efficiency was obtained with the increase in pitch, and in the experiments made the limit of improvement did not appear to have been reached. With the narrower blades the maximum efficiency obtained was for a ratio of pitch to diameter of about 0.80. The investigation of the effect on the efficiency of variation in pitch will be continued.

Experimental Work on Full-sized Aeroplanes.—It was mentioned in last year's report that arrangements had been made for conducting full-scale experiments. These were commenced early in 1911 under the direction of the superintendent of the Royal Aircraft Factory. The earlier work was directed to the determination of the effect of various modifications in an existing machine. An aeroplane of Farman type was available for the purpose, and the alterations made aimed at diminution of head resistance by various means; the increase of mechanical efficiency by improvement of propeller design and correct correlation of propeller and engine; improvement in the design of the wings; increased ease of control; and improved directional stability. In all these respects satisfactory results have been attained; the alterations have effected a marked improvement in ease of control, stability and speed, with increase of available lift. In connection with this work a standard form of "speed-resistance" and "speed-horse-power" curves has been adopted for setting out the qualities and performances of aeroplanes. This has been found very convenient for purposes of design.

Attention is also being given to the problem of obtaining during actual flight measurements of the principal quantities affecting the behavior of the machine, a knowledge of which is necessary to enable the conditions of flight to be accurately analyzed. Apparatus has been designed for recording the propeller thrust on machines in flight, and measurements are also being made of the relative wind velocity and the gliding angle, while the effect on the stability of modifications in design is being specially studied.

Meteorological Work.—In April, 1911, the Lords Commissioners of H. M. Treasury sanctioned the establishment, by arrangement with the War Office, of a branch of the Meteorological Office, in connection with the Royal Aircraft Factory, at South Farnborough, to supply meteorological information to those engaged in field work, and to carry on the investigation of the upper air for the Advisory Committee under the direction of the Meteorological Office. Mr. J. S. Dines was appointed by the Meteorological Committee as meteorologist in charge of this branch office. Suitable accommodation for this experimental observatory was included in plans prepared for additional buildings at the Aircraft Factory.

This new branch of the Meteorological Office, for which accommodation is to be provided during 1912, is designed to fulfil three functions:

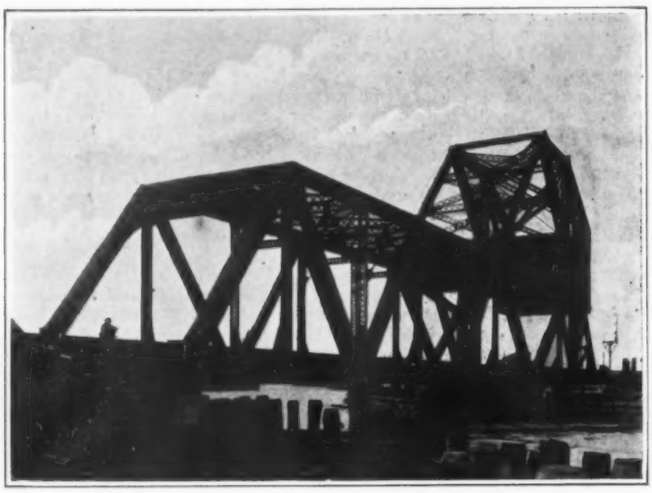
1. To supply meteorological information and forecasts in a form directly applicable for the guidance of airmen.
2. To carry on the experimental work for the Advisory Committee.
3. To act as an observing station for the Meteorological Office.

Vertical Motion in the Air.—Experiments on vertical air currents have been carried out during the past year by means of balloons tethered to a point on a steel tower 95 feet above the ground, with a view to the determination of the angular deviation from the horizontal of air currents at a moderate height. The method consists in following the motions of such a tethered balloon with a recording theodolite. The analysis of the records shows that the inclination of the wind direction to the horizontal does not normally exceed 20 degrees, though on one occasion a downward current was observed making an angle of 43 degrees with the horizontal, corresponding in this instance with a vertical component of the wind velocity of about eight miles an hour. As a rule, the larger deviations from the horizontal were not met with on days of strong winds.

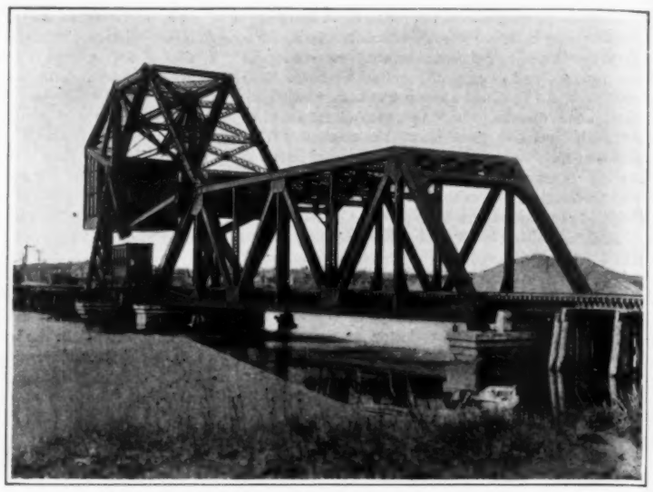
The Study of Gusts.—Some account was given in the previous report of the variation found in the gustiness of the wind at different levels. A comparison has been obtained during the past year of the gustiness at two points, respectively, 36 and 98 feet above ground, the measurements being made by means of a pressure tube anemometer head. The gustiness at 36 feet was found to be about 30 per cent greater than that at 98 feet, for the site where the experiments were made.

In connection with the work on vertical motion, records of wind velocity were taken with a more open time scale than is usual, and these have given some further information of value with regard to gusts. In a gusty wind of normal type, a rise of wind velocity is usually followed almost immediately by a fall of approximately equal amount. In some of these observations, however, cases were found in which a sudden access of wind velocity persisted for at least one minute. Thus a case is recorded in which the wind rose suddenly from 13 to 23 miles per hour, followed by a slight fall and then a further rise to 28 miles per hour; the wind remaining above 20 miles per hour for more than one minute after the first rise. Attention is directed to this special type of velocity change on account of the probability that similar phenomena, though possibly of greater intensity, in the upper air currents may explain one of the types of conditions commonly known in the language of airmen as "holes in the air."

Experiments in progress on the wind towers give some valuable information as to the width of gusts, i. e., as to the lateral variation in the velocity of the wind. From observations taken at two points 40 feet apart in a line approximately at right angles to the direction of the wind, the conclusion is drawn that the pressures due to the wind velocities at the same instant at two points 40 feet apart may differ by as much as 50 per cent and will frequently differ by 25 per cent. Differences of corresponding amount must, therefore, occur in the velocities of the natural wind striking the two wing tips of an aeroplane; thus, in a wind of 10 miles an hour, for an aeroplane traveling at 50 miles an hour, the difference between the pressures at the wing tips might amount to 10 per cent. The observations were, for the most part, taken in strong winds of the order of 30 miles an hour, but the same proportionate variation has been found in lighter winds, though of course with diminution in the mean velocity of the wind the gusts become of less importance.



The Bridge at Ashtabula Harbor in Its Closed Position.



Electrically Operated Bascule Bridge at Cape Cod.

Electrically Operated Bascule Bridges

The "Heel Trunnion" Type

THE accompanying illustrations and drawings show a new form of electrically-driven bascule bridge with fixed trunnions and overhead counter weights. Two of these 160-foot double-track span bascule bridges have been constructed for the N. Y., N. H. & H. R. R. bridge across the Cape Cod canal and for the Lake Shore & Michigan Southern Railway at Ashtabula Harbor, Ohio.

The electric motors used on these electrically-operated bascule bridges are of the direct-current type, developing 65 electrical horse-power.

The accompanying drawings show the method of operation of the "Heel Trunnion" bascule bridge and indicate the construction of the Duwamish River bridge at Seattle, Wash., of the Northern Pacific Railway. This single track bridge is operated by two direct-current electric motors, each having a capacity of 25 horse-power. It may be stated that of the eight large bascule bridges of the "Heel Trunnion" type which have been completed in the United States and at Winnipeg, Man., Canada, the operating mechanism is the same, electric power being used, although the equipment is arranged for emergency hand operation also, while the Cuyahoga River bascule bridge is also provided with a gasoline engine equipment, the oil motor being installed in a stationary inclosure at the trunnion. This gasoline motor is connected to the moving leaf of the bridge by bevel gears and a shaft turning in the bearing bolted to the outside web of the end post of the bridge truss.

The Cuyahoga River and Illinois River bridges were erected in an open position without interfering with navigation, at all times maintaining an open channel, while the Seattle bridge, as well as those at Ashtabula Harbor and Cape Cod canal were erected in a closed position.

In all of these "Heel Trunnion" bascule bridges the main trunnion is located in the bottom chord of the truss, about which the moving leaf pivots, this being a fixed pivotal point as is also the counter weight trunnion, located at the apex of a fixed triangular collar about which the counter weight frame and concrete counter weight pivot.

The counter balancing is applied to the moving leaf through a counter weight link connected to the truss and counter weight frame by means of pins at either end, this link being parallel to and equal in length to a line joining the main trunnion and the counter weight trunnion.

The center of gravity of the whole structure does not move either vertically or horizontally as the bridge is being opened or closed. The dead load pier reactions are vertical and constant for all positions of the bridge and the dead-load reaction of the rest piers is zero whether the bridge is opened or closed.

The dead-load reaction of the counter weight pier is practically equal to the weight of the counter weight and tower, while the dead-load reaction of the trunnion gear is equal to the weight of the moving leaf.

These conditions are brought about by the separation of the points of support of the counter weight and the moving leaf, but at the same time combining their pin reaction through the connecting members of the parallelogram, causing a resultant vertical and constant load on the piers.

The foundations of this type of bridge are both economical and simple to construct, for the reason that the combined center of gravity of the component parts of the bridge structure does not move as the bridge operates, either vertically or horizontally, and the troubles arising from concentrating all the load of the bridge on one pier are avoided by separating the reaction of the counter weight and moving leaf.

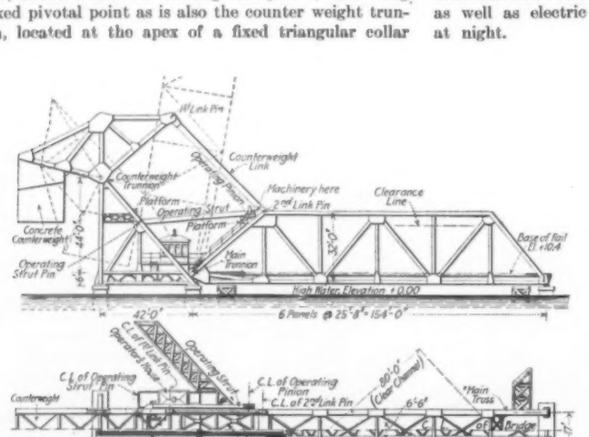
There is a target placed at the end of the leaf on the lower chord and another at the top of the pier, in order to guide the attendant in closing the bridge, these targets have different colors for the two halves, so arranged that when the bridge is closed properly the different color halves of each target are directly opposite each other and in plain view. There are oil lamps as well as electric lamps for illuminating the target at night.

There is an air cushion located at the center line of the bridge and attached to the front-end floor-beam, consisting of a piston and air cylinder, with a rod which strikes a plate bolted on the rest pier, and as the bridge closes the air is compressed in the cylinder so as to absorb the shock. There is a valve on the cylinder which can be so regulated that the air may be compressed as occasion requires to a greater or less degree, but it is maintained that the perfect balancing of the bridge in its construction is such that these air cylinders are not really necessary but are installed merely as a precautionary measure. The locking is effected by means of a latch-bar located under the center line of each truss which moves in a guide attached to the bottom chord.

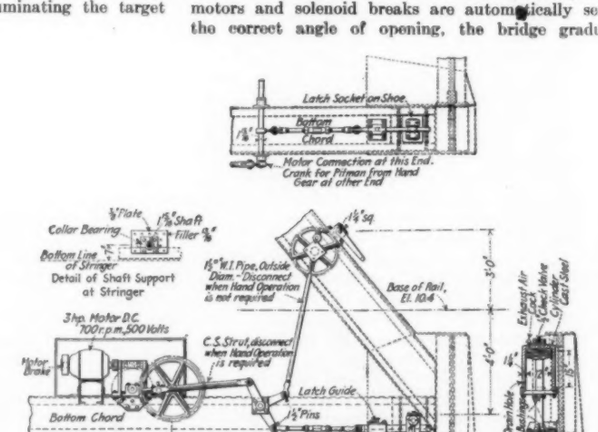
This latch-bar passes through rectangular slots in diaphragms between the gusset plates of the truss, fitting securely into a casting provided with a roller. This permits easy movement of the bar longitudinally, the casting with the roller being bolted on an extension of the bridge shoe upon which the truss rests. Emergency hand operation is provided for the end lock in addition to the three horse-power electric motor which usually serves the purpose.

It is not possible to apply electric power for opening the bridge locks until the train signals are set at "Danger" and the bridge is completely closed to train traffic, and in a similar manner it is impossible to apply electric power for opening the bridge until the locks are fully open, this being accomplished by so connecting the operating electric motor circuit with the lock-motor circuit that the actual movement of the locks and bridge automatically complete and break the electric circuit of each operating motor in the proper order by means of contact switches.

Electric power is available for holding the bridge down on its seat firmly while driving the locks in closing the bridge. When the bridge reaches an angle several degrees less than the total angle of opening, the current is automatically cut off from the operating motors and solenoid breaks are automatically set at the correct angle of opening, the bridge gradually



Elevation and Plan of the Electrically Operated Bridge.


Latch Socket on Shoe
Bottom Chord
Motor Connection at this End. Crank for Pitman from Hand Gear at other End
Collar Bearing
Shaft
Filler
Bottom Line of Stringer
Detail of Shaft Support at Stringer
Base of Rail, El. 10.4
3 hp. Motor D.C. 700 r.p.m. 500 Volts
C.S. Strut, disconnect when Hand Operation is required
Motor Brake
Latch Guide
Bottom Chord
Pins
Steel Latch Bar Finished all over. Diam. Roller
Plate

End-lock and Buffer of Bascule Bridge at Seattle.

and smoothly coming to rest without shock or jar.

The operator's cabin containing the electric controllers and switch board is located in the interlocking tower, but some distance away from the bascule in the bridge over the Illinois River at Peoria, while the operator's house is located close to the bascule in the interlocking tower at the Ashtabula Harbor bascule bridge. The electric controller house at the Seattle, Cleveland, and Cape Cod bascule bridges is located on the brackets extending from the tower base, but with these slight differences in the location of the electric controlling apparatus, the operation of the several bridges is the same.

There are signals provided to correspond to the different positions of the bridge and lock. These signals consist of incandescent lamps showing through colored lenses and are automatically lighted when the position of the bridge or lock is reached which they are intended to indicate. These electric signals are located in the operator's cabin in such a position that he can readily see them at all times while manipulating the electric controller for opening and closing the bridge.

These electrically-operated bridges of the "Heel Trunnion" bascule type are noiseless and rapid in opening and closing and have been found to be thoroughly reliable under the most severe conditions of service.

Screening as an Anti-Malaria Measure*

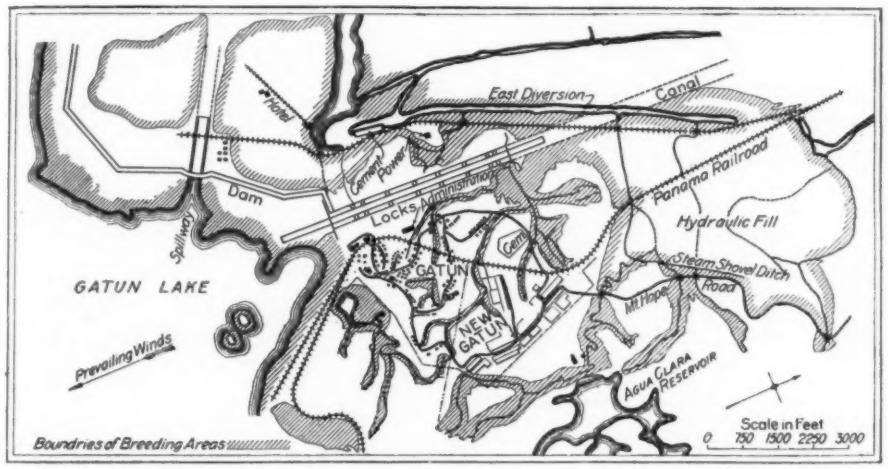
A Contribution on the Value of Screened Dwellings in Malarial Regions

By Dr. A. J. Orenstein, Assistant Chief Sanitary Inspector, Department of Sanitation, Isthmian Canal Commission

WHAT seems to the writer an unusal opportunity for studying the value of screening against mosquitoes in a country where malaria is endemic and rather prevalent, exists in the settlement of Gatun in the Canal Zone.

The present settlement of Gatun was founded in 1906, primarily for the accommodation of the employees engaged in the construction of the canal, for whom a number of houses and barracks were built by the Government, all of these buildings of course being thoroughly screened with the approved eighteen-mesh copper gauze.

Early in 1908 it became necessary, because of the process of canal construction, to remove the ancient village of Gatun, which was situated within the canal prism. In order not to impose unnecessary hardship upon the inhabitants of this village, it was decided to offer these people lots to the north of the new settlement of Gatun on land owned by the Panama Railroad. By the middle of 1908 quite a settlement of West Indians and natives grew up in this vicinity, and by 1909 the number of inhabitants in the settlement to the north of Gatun, which became known as New Gatun, reached approximately 5,000, of whom about 2,500 West Indians and Europeans are employees of the Canal Commission. In New Gatun the houses are not screened.



The Mosquito-breeding Areas Near Gatun.

Reference to the attached sketch map shows the relative geographical position of Gatun and New Gatun. Attention is especially invited to the relative position of the Anopheles breeding areas to Gatun and New Gatun. The Anopheles breeding areas are outlined by cross-hatching on the map. A glance will show that the distance of mosquito flight from these breeding areas to Gatun and New Gatun is about equal.

The population of the Government settlement of Gatun (and hereafter in this paper "Gatun" will be used to designate the screened and "New Gatun" the unscreened settlement) is composed of approximately the following employees: About 500 Americans living in bachelor quarters, about 1,500 white Europeans living in barracks, about 200 white Americans living in married quarters, about 1,000 black West Indians living in barracks, and about 1,300 others living in miscellaneous quarters, such as dredges, police station, hospital, cars, etc. All of these employees live in screened quarters.

The employees living in Gatun and New Gatun are engaged in approximately the same work, i. e., in the excavation and in lock and dam construction in the vicinity of Gatun. They all work approximately the same hours, and in so far as malarial incidence is concerned, the two settlements differ in only one respect: Gatun is screened and New Gatun not screened. It will therefore be interesting to note the malarial incidence for the employees of the two towns, and this incidence, expressed in percentages of the number of employees residing in the two settlements, is shown in Table 1.

A brief explanation as to the method used in computing percentages of malaria might not be out of place.

At the end of each week the District Physician reports to the Chief Sanitary Officer the number of cases of malaria seen by him during that week. In the office of the Chief Sanitary Officer the number of cases of malaria for each district are then computed as percentages of the total number of employees residing in the district.

In arriving at the "Average Monthly Percentage" of employees for Gatun and New Gatun, the weekly percentages for each year were added and the sum divided by twelve, thus arriving at an average per month for each year.

To make this even more plain, it may be stated as follows: Taking 1910 as an example, 4.01 per cent for Gatun means that during each month of that year an average of 4.01 cases of malaria to each 100 employees residing in Gatun were seen by the District Physician.

TABLE 1.—MALARIA INCIDENCE IN GATUN AND NEW GATUN.

(Shown as average percentage of malaria cases per month of total number of employees residing in the two settlements.)

Year	Gatun	New Gatun
1908 (Two and a half months)	6.32	5.59
1909 (January to August)	3.70	7.47
1909 (September to December)	6.45	6.86
1910	4.01	5.37
1911	5.25	6.51

The figures for 1908 begin with the middle of October. The percentage of malaria cases for 1908 and 1909, from January to August, inclusive, refers to malaria cases admitted to hospitals in relation to the total number of employees living in the two towns, i. e., malaria patients who were not sick enough to be sent to a hospital were not taken into account in computing these percentages. From September, 1909, for 1910 and 1911, all cases of malaria occurring among employees, even though the attack was not severe enough to cause their admittance to the hospital, but merely kept them from work for half a day or more, are taken into account.

Taking into consideration the total period of the existence of New Gatun and Gatun, the relation of the malaria percentage of Gatun to that of New Gatun is as 51 is to 63.

But another factor comes into play: Anopheles adults are most numerous during the months of May to September, inclusive. It is during these months that the maximum number of malaria cases develop on the Canal Zone, and it is during these months that the number of primary cases, i. e., cases of primary infection, predominate. During the remainder of the year recrudesences predominate. It therefore follows that the value of screening is best demonstrated during the months of May, June, July, August and September, and would be shown better by referring to the malaria percentages of the two settlements, taking only these five months into consideration. These percentages are shown in Table 2, which gives, for these months of each year, the average per month incapacitated for duty by malaria.

TABLE 2.—MALARIA INCIDENCE IN GATUN AND NEW GATUN.

(During the months of May to September, both inclusive, of each year. Shown as average percentage of employees residing in the two settlements.)

Year	Gatun	New Gatun
1909	5.35	10.04
1910	5.37	9.21
1911	8.75	12.59

During these months of greatest Anopheles prevalence the relation of malaria incidence for Gatun and New Gatun is as 2 to 3, i. e., for each two cases of malaria among the employees residing in Gatun there were three cases of malaria among the employees residing in the unscreened houses of New Gatun.

The deaths from malaria among the employees residing in the towns of Gatun and New Gatun are shown in Table 3. But the figures given do not show two factors of great importance in the consideration of the value of screening.

TABLE 3.—DEATHS FROM MALARIA AMONG EMPLOYEES.

Year	Gatun	New Gatun
1909	5—1 per 1,000	4—2.7 per 1,000
1910	9—1.7 per 1,000	4—1.6 per 1,000
1911	2—0.4 per 1,000	3—1.2 per 1,000

First: The employees residing in the screened quarters are not allowed to remain in the barracks unless they have a certificate from a physician. This results in the physician's seeing every case of malaria occurring among the employees residing in the screened quarters. The employees residing in the unscreened New Gatun, however, quite frequently do not visit a physician when suffering from a slight attack of fever.

Second: The proximity of the unscreened settlement with its large number of malaria carriers furnishes a number of infected Anophelines, thus affecting to some extent the employees residing in the screened quarters, who quite frequently spend their evenings in New Gatun.

This seems an opportune place to reiterate a few maxims of effective screening against mosquitoes:

1. Screening to be effective must be thorough.

2. A screened dwelling with cracks, ill-fitting doors, tears in the screening, corrugated iron siding and roofing with openings between the corrugations and the plate not properly closed, and various other minor defects, is probably worse than an unscreened dwelling, for into such a house mosquitoes will readily find entrance, and once having entered will not leave.

It has been proved beyond peradventure, experimentally, that mosquitoes will gain entrance through a very small aperture, and once in an inclosure seem to be unable to find their way out through a small aperture.

3. The wire gauze screening must have a sufficient number of strands per square inch to insure the impossibility of mosquitoes entering through the apertures between the strands. Eighteen-mesh gauze is used in the Canal Zone, and this gauze has proven effective. The gauze must be non-corrosive.

4. The screening must be stretched tight. This will prolong its life and will make cleaning easier.

5. All doors should open outward, should be provided with an efficient self-closing device, should be so hung that they will not easily warp or sag, and should have the screened panels protected from injury by the hands and feet of the users.

6. Windows should not be fitted with removable or sliding screens. Practice has shown that the average person will not use care in keeping such adjustable screening carefully closed so as to be tight against mosquitoes.

* Reproduced from the *Engineering Record*.

Considerable has been written about mosquito screening making rooms darker, and, especially, hotter.

In the climate of the Canal Zone, with the temperature seldom rising above 94 degrees and an average day temperature of approximately 80 degrees, screening has not been found to cause any discomfort. However, the highest grade of copper gauze is used, and the screening is kept free from dirt and the products of corrosion by frequent brushings and careful handling of same.

To sum up:

1. A properly screened dwelling can be depended upon to reduce by at least one third the malaria incidence in a locality where malaria is endemic.

2. In order to be effective, screening must be carefully planned, well installed and kept in good repair.

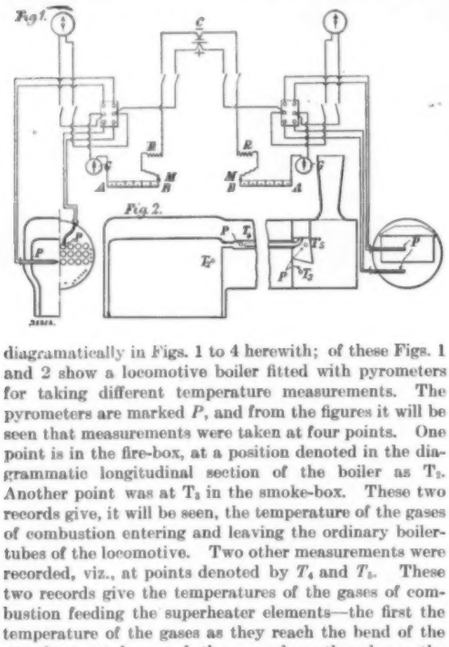
3. In so far, at least, as Canal Zone experience goes, screening with eighteen-mesh copper gauze has not resulted in appreciably reducing the light or materially increasing the heat in the dwellings.

I am indebted to Col. W. C. Gorgas, Chief Sanitary Officer, for permission to publish this paper, and to Mr. Patrick Mahoney for his aid in going through the large number of records on which the tables given in their papers are based.

Temperature Tests on Superheater Locomotives

The Influence of the Conditions of Working

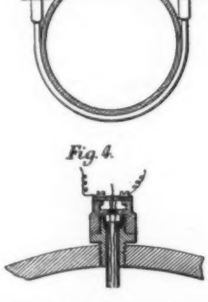
PARTICULARS of some interesting temperature tests carried out on superheater locomotives on Russian railways by Prof. Lomonsoff and M. Czeczott are given in a recent number of *Engineering*. These tests relate principally to the variation of temperature of the gases of combustion under different conditions of working. The apparatus employed in securing these records is shown

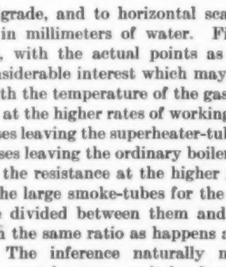


diagramatically in Figs. 1 to 4 herewith; of these Figs. 1 and 2 show a locomotive boiler fitted with pyrometers for taking different temperature measurements. The pyrometers are marked *P*, and from the figures it will be seen that measurements were taken at four points. One point is in the fire-box, at a position denoted in the diagrammatic longitudinal section of the boiler as T_2. Another point was at T_3 in the smoke-box. These two records give, it will be seen, the temperature of the gases of combustion entering and leaving the ordinary boiler-tubes of the locomotive. Two other measurements were recorded, viz., at points denoted by T_4 and T_5. These two records give the temperatures of the gases of combustion feeding the superheater elements—the first the temperature of the gases as they reach the bend of the superheater tubes, and the second as they leave the superheater. It is believed that this is the first attempt to take temperature records within the large smoke-tubes at a point such as that denoted by T_4.

The wiring for the instrument is shown in Figs. 1 and 2. The method employed was described in the *Zeitschrift des Vereines Deutscher Ingenieure*, 1909 (No. 9), having been devised by Mr. Kroukovsky, Professor of Electro-Technics at the High School of Mining at Ekaterinoslav. Its essential feature is that, instead of using sensitive voltmeters in connection with the pyrometer, a compensated galvanometer is used, and the apparatus so arranged that all readings are taken with the pointer at zero. The result of this is that a robust instrument, little likely to be affected by the vibration of the train, can be used and yet accurate readings obtained. In the installation under notice the instruments are in duplicate and the connections for the four pyrometers are taken to two switches, so that readings for all four can be taken on two scales. The reading instruments were all in the dynamometer car behind the tender. In the diagram, Fig. 1, *C* peresents the cell; *G, G* represent the galvanometers, of about 4.5 ohms resistance; *R, R* the rheostats; *A B, A B* scaled resistances; and *M, M* cursors which slide over the scales *A B, A B*. Two check instruments are also inserted in the circuits. When taking records the cursor *M* is moved along the resistance scale *A B* until the galvanometer pointer is at zero, when the reading of the scale *A B* gives a measurement of the temperature. The method of inserting the pyrometer into the large smoke-tubes, in order to secure temperatures at the point T_4, is shown in Fig. 3, while in Fig. 4 is shown the manner in which the connections for this pyrometer were carried through the boiler-shell.

The results of some of the experiments are shown in Figs. 5 and 6. These are plotted to vertical scales of

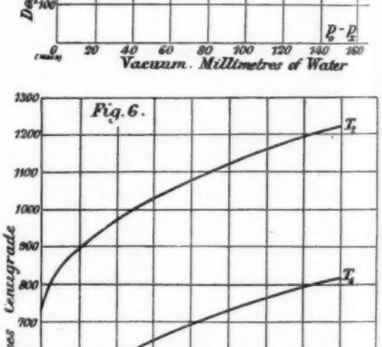


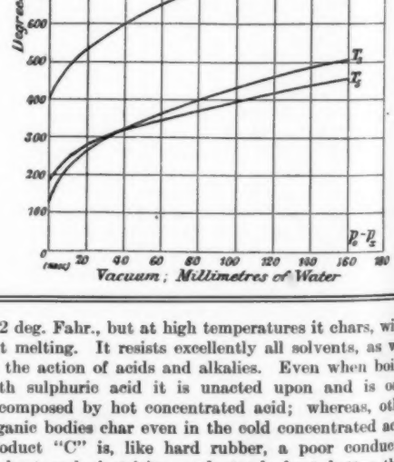


degrees Centigrade, and to horizontal scales of smoke-box vacuum in millimeters of water. Fig. 5 shows a typical curve, with the actual points as recorded. A feature of considerable interest which may be noticed in connection with the temperature of the gases leaving the barrel, is that at the higher rates of working the temperature of the gases leaving the superheater-tubes is less than that of the gases leaving the ordinary boiler-tubes. This suggests that the resistance at the higher rates becomes too great in the large smoke-tubes for the gases of combustion to be divided between them and the ordinary boiler-tubes in the same ratio as happens at low rates of combustion. The inference naturally must be that superheat does not increase, as it is often contended it does, at a rate varying directly with the rate of combustion or draught, but that the rate falls off at the higher rates of working. This is confirmed by a study of other tests.

These experiments were conducted by Prof. Lomonsoff and M. Czeczott on the Tashkent Railway, and incidentally these investigators found that moisture was present in the steam at the dome, usually to the amount of 4 to 5 per cent, while many instances of 10 per cent moisture had been recorded. These figures confirmed results obtained by these experimenters independently on the Ekaterinynsky and Rybynsky railways; and it is their opinions that these are ordinary figures for waters containing appreciable quantities of carbonates.

The locomotive on which the above temperature tests were made had cylinders 550 millimeters by 700 millimeters (21.6 inches by 27.6 inches), driving-wheels 1,830 millimeters (6 feet) in diameter, and total heating surface of 205.4 square meters (2,210 square feet), of which 41 square meters (441 square feet) was super-heater surface. The length of the tubes was 4,420 millimeters (14 feet, 6 inches); the grate area, 2.8 square meters (30 square feet); the working pressure, 13 kilogrammes per square centimeter (191 pounds per square inch); and the total weight of engine, about 73 tons. The bends of the superheating elements were 670 millimeters (26.8 inches) along the smoke-tube from the fire-box end.





Substitutes for Hard Rubber and Celluloid

THERE are already on the market, says a writer in *Der Technische Handel*, many substitutes for celluloid, which have the unpleasant camphor odor, and for hard rubber, which by reason of the high price of crude rubber is hardly to be had at any price; but none of these substitutes, such as "Zellit," "Zeltit," etc., on the one hand, "Gummit," "Gummon," "Ambroin," etc., on the other, is anywhere near fit to replace celluloid or hard rubber with the many good qualities of these two substances. For this reason, much attention has been directed to a newly discovered gum, which has very nearly the properties of the materials last named, and which the chemist Baekeland has produced by synthesis. The new material is called after its inventor or discoverer, Bakelit.

Other experimenters had attempted earlier to produce gums by synthesis, but none of them had succeeded in producing as a final product a gum of constant homogeneous physical qualities. Based on those researches, Baekeland has found a process which permits always obtaining the same products, whether they be fluid, viscous, colloid or solid, as desired.

The method of procedure is as follows: Equal parts of phenol and formaldehyd are mixed together, and the mixture decomposed by the aid of heat and an alkaline material such as soda. There are thereby formed two layers, of which the lower one represents the initial condensation "A." This product "A" can be produced in all degrees of consistency, and is soluble in alcohol, aceton, phenol, glycerine, and soda lye. Pulp board, or wood, saturated with the material and then dried, is made hard and thoroughly resistant to acids and fire. The solid mass is brittle and fusible.

If the solid product "A" is heated under pressure in a so-called "Bakelisator" it is changed into product "B" or "C," according to the duration of the heating process.

Substance "B" is solid at all temperatures, brittle, and at ordinary temperatures harder than "A." It is insoluble, and in aceton, phenol or terpinol, only swells up. Under the influence of heat it becomes softer and elastic, without melting; but on cooling, it resumes its original brittleness.

Product "C" is infusible, softens hardly at all with heat, and stands a temperature of 300 deg. Cent. to 572 deg. Fahr., but at high temperatures it chars, without melting. It resists excellently all solvents, as well as the action of acids and alkalies. Even when boiled with sulphuric acid it is unacted upon and is only decomposed by hot concentrated acid; whereas, other organic bodies char even in the cold concentrated acid. Product "C" is, like hard rubber, a poor conductor of heat and electricity, and stands heat better than hard rubber does. It is also much harder than hard rubber, and can compete very well with this latter in price; but it is entirely devoid of the wonderful elastic and flexible qualities of hard rubber; and this is its principle fault. But in all other properties it is superior to all similar products.

To Protect Wood from Boring Worms.—Articles can be protected from the wood worm, according to the *Arbeiter und Schrebergarten*, by a liquor made from a decoction of 1 part common salt, 1 part pepper, 1 to 2 parts crushed mustard seed, 1 part garlic and 1 part of wormwood leaves, in 2 to 3 quarts of spirit of vinegar. With this mixture the articles to be protected from the wood worm should be twice coated.

Reading a Book-Page Instantaneously*

A Case of Unique Visual Power

By George M. Gould, M.D.

One of the author's patients, a certain Mr. C., had the power of reading a page of an ordinary book, duodecimo or octavo at a glance. His eyes and attention were fixed on the page for but a second or two, and it was read, its statements or contents so fixed in memory that they could be brought forth from that "vasty deep" whenever in after-years desired. Page after page was thus read; and book after book, year following year. Several volumes might thus be gleaned in an evening. It scarcely needs the saying that it was necessary that the book should be "easy reading," its English of good style, the subject treated not essentially unfamiliar, recondite, or philosophic, but within the easy grasp of the man's intellect, such as well-written novels, narrative, history, essays, poetry, the magazines, etc. In reading poetry, of which he was extremely fond, he could by a glance store his memory with the line or stanza of a page or poem which to his critical judgment stood out with superior excellence.

This ability began to show itself in late midlife, growing more and more perfect in his later years. It was often put to the test by his assistants or secretaries, and more frequently he vainly tried to prove that they possessed the same celerity of reading as himself. Not one could even remotely rival him. In directing such tests by others he persistently urged that they could carry them out as speedily and correctly as himself, if they followed his own rule and habit, namely, fixing the gaze and attention on the center of the page, thus causing at once the entire page to swim into view, to be perceived and to be photographed in memory. He was scornful of the ordinary fashion of reading line after line, or sentence after sentence. Of course none ever succeeded in reading as did he, and he could not understand it; he was even vexed by it, and bluntly said that their inability was due to mental causes or lack of exercise. He never dreamed that his ability in the act of reading so rapidly sprang from a strange peculiarity of disease in his own eyes.

Every student of vision knows that, as a general fact, it is optically impossible for the two normal and immobile eyes to look intently on a small object such as a word or two in the center of a page, and at the identical instant, see and understand all the sentences at the limits of the page above, below, etc. The structure of the human retina and the history of its function absolutely forbid that. The "field of vision," it is true, may be thus mapped, and its widest boundaries localized by means of the mere existence of illuminated objects placed at the periphery, i. e., by the perimeter —but that is not intellectual vision, and memory is not called in.

Mr. C. was a man of exceptional learning, his mind being highly trained in literary criticism and creation. It was because of his marvelous celerity in acquiring knowledge that he seemed to his associates to do far less reading than men of vastly inferior erudition. His memory was almost faultless, and he was famous for his unerring judgments and epitomes of literary history and productions, all drawn from his own personal reading and research; and, if desired, or desirable, illustrated, also, by accurate quotations.

Optically considered, it all appeared primarily to be the result of a marvelous, even an impossible, perfection of the visual mechanism, united, of course, to a mental outfitting of exquisite sensitiveness, infallible memory and extraordinary intellect. No question may be raised as to these last-named endowments of his mind, but pertaining to the very large and primary part played by the eyes themselves, the phenomenon was based solely on a pathologic lesion—it was due to disease. It was, in truth, a rare but not the first instance of physiologic function perfected through life's splendid ingenuity and repair, even re-creation, out of the mangled left-overs of morbidity and disorganization.

There have been many reported instances of clairvoyant knowledge—flawless reading, for instance, of any closed book chosen. The case in question was not of this sort. But it is rationally and scientifically explainable when all the facts are known and intelligently studied.

The strictly normal, but extremely high and perfect mental functions of the man being given as prerequisites of his power of seeing and memorizing the printed page, there is still necessary a fundamental, and seemingly unique peculiarity of the merely ocular act. Without it there is no scientific explanation of the completed result. Accurate knowledge of the physiology of binocular or two-eyed vision, and an intimate understanding of the peculiar ocular disease of this man are required to solve the mystery.

He was right-handed, and therefore in early life he was, of course, right-eyed. (Right-eyedness is the cause of right-handedness.) Sometime during the middle years of his life the central part of the retina, the "macular" region of the right eye, was destroyed by an inflammation (chorioditis), caused by eye-strain. The "fixing" part of the retina was obliterated, leaving there a blind, black, round, disorganized, pigmented space or hole. The left eye was not diseased and continued the usual perfection of macular or central vision. By long, unconscious and forced exercise, the healthy zone of the normal right retina surrounding the macula was educated to such a degree and so widely that it could, when unmoved, receive and transmit to the brain the image of the entire page, except that part falling on the central portion which had been destroyed. This was naturally supplied in perfection by the macula of the left eye. If, like two cups or saucers, one retina were placed within the concavity of the other, the "identical points" superposed, it would be seen that the size of the normal zone of retinal macular or central fixation of the sound left eye would exactly cover and complete the pattern, and act for that space destroyed by disease in the right eye. The right eye could not fix on and see the center of the field or object; it could only be held on this unseen point by the left eye, could only stare at it, if one may so speak. The cerebral visual center thus received the entire photograph of the object seen, made complete by the complementing interaction and unitizing function of the two eyes.

That the visual axis of the left eye acted on a healthy macula, and "fixed" the usual extent of the picture there, supplementing the coextensive blindness of the right eye, is thus explained; and one understands how, with both eyes, there was no failure or imperfection of the photograph. There remains the lesser mystery of a large extension of the sensitive and reacting retina of the right eye toward its borders or periphery.

This is more readily explained. In the common eye of mankind the accuracy and perfection of imaging in the more outlying retinal regions lessens with every degree traveled toward the periphery. But some relative accuracy is retained in all parts, and this, beyond doubt, is capable of increased education. It is a well-known fact that the creation, functionally, of a new macula frequently takes place at some distance away, when the original macula has been destroyed. Some birds have two normal maculas. In the present peculiar case the striving after a new macula would be, and certainly was, replaced by exceptional sensitizing, enlarging and educating of the greater zone surrounding the lost macula. This trend or necessity was aided by the fact that being originally right-eyed, this man's right eye, after the loss of its central vision, held, in part at least, to its natural right and habit of dominancy; and thus, while its axis of vision remained immobile, there came an increased and widened power of synchronous response to the picture-stimulus in the more outlying zones. Neurology readily understands and explains how the cerebral centers of vision united the two fields, unmarred, into one sensational photograph. The extremely sensitive and highly endowed brain thus seized on the disadvantages of disease and turned them into a superbly valuable excellence. This anomalous acquirement of synchronous large-space reading was a great aid to the man as student and master of literature.

It may be added that a normal pair of eyes, without any lateral motion, is able to read printed lines at 15 inches distance, only when such lines are from about ½ to 1 inch long. To extend this length of line to 3 or 4 inches, as in the present case, and synchronously to visualize intelligently thirty or forty lines, is beyond question impossible for the normal visual mechanism. But to such eyes as those of Mr. C. it would not only be possible, but, well considered, natural. That the extramacular zones of the eyes are capable of increased and heightened susceptibility and education is well illustrated by the fact that a child learning to read can fix on only one letter at a time; by and by he acquires the ability to take in a word; then, later, several words, and in adult life, perhaps a sentence. But there is then more than a suspicion of some unperceived lateral motion of the axes of vision. Narrow columns, and white instead of black letters, would surely add to this larger oversight. But all such acquirement differs in fundamental mechanics—or neurology—from that of Mr. C.

It appears clear to me that so long as the two eyes retain the habitual functions of the two normal macular regions there can never be such a marvelous extension of synchronous and perfect peripheral vision as was illustrated in Mr. C.'s case. That is possible only when one macula is destroyed, with retention of the perfect peripheral portions. We have thus the strange paradox that a man may gain by a physical injury.

* Reproduced from the *Journal* of the American Medical Association.

The Action of Radium Rays on Blue Sapphires and Blue Rock Salt

By Dr. A. Miethe

It is well known that radium rays produce peculiar changes of color in many minerals. I wish here to describe some experiments which appear to indicate a remarkable connection between the coloration of blue sapphires and that of the so-called blue rock salt.

Sapphires belong to the class of gems which are most changed in color by radium rays. In the last five years I have exposed to these rays many hundreds of sapphires of various origin and also some artificial blue sapphires made by the Deutsche Edelstein-Gesellschaft.

Natural sapphires of different origin behave very differently under the dichroscopic lens. As, however, the origin of cut stones is often uncertain I prefer to classify the stones by their behavior, rather than by their origin. One group is composed of the colorless pale yellow or pale blue sapphires whose origin is usually given as Ceylon. I have examined a great many of these stones, both cut and uncut, which undoubtedly came from Ceylon. In accordance with their light color they showed scarcely any appreciable dichroism under the dichroscopic lens.

Dark yellow natural stones show traces of dichroism in the form of a lighter yellowish-green and a darker orange-colored image. The pale blue Ceylon sapphires show either no dichroism or a very feable one, in which the two images differ only in brightness but not in color. Dark blue Ceylon sapphires usually show a deep blue and a violet image, less frequently a deep blue and a light gray-blue image. The Australian sapphires behave very differently. These stones, which are always very dark cyan-blue, gray-blue or green-blue and frequently show yellow or greenish yellow patches, exhibit under the dichroscopic lens a deep blue and a light yellow-green, gray or green-blue image.

Still different phenomena were shown by blue sapphires, supposedly from Cashmere and Burma, some of which, like the dark Ceylon stones, gave a blue and a violet, or a very dark blue and a light gray-blue image.

The paler artificial sapphires usually give two blue images differing in brightness, but very little in color, while the darker stones show a very deep blue image beside a lighter gray-blue one. Among the artificial stones, however, are found many which resemble the Ceylon sapphires and a few which resemble the Australian sapphires in behavior under the dichroscopic lens.

As all the artificial stones were made by the same process, so far as I know, it appears probable that these differences are caused by impurities in the clay used in their production.

Similar impurities probably account for the variety in the behavior of natural stones. Nothing certain is known of the cause of the color of natural stones; some authors attribute it to iron and titanium, others to organic ingredients.

In regard to their behavior under radium rays natural sapphires may be divided into three classes. The first class consists of colorless, pale blue or light yellow stones, and includes all the light colored Ceylon sapphires. In this class strong preparations of radium

* Translated for the Scientific American Supplement from *Prometheus*.

intensify the yellow tint with extraordinary rapidity: pale yellow stones becoming deep yellow, colorless stones straw colored or golden, and pale blue stones light yellow or yellowish-green. These changes are not permanent. For example: the yellow tint produced in the pale blue stones by from twelve to twenty-four hours radiation vanishes rapidly in daylight and slowly in darkness, and in four to eight weeks the original bluish tint is completely restored. Similarly the changes produced by radiation in the colorless and pale yellow stones disappear, though less rapidly. The last-named stones are also deepened or darkened in tone by cathode rays and by ultra-violet rays, and these changes likewise gradually disappear.

Quite different is the behavior of the dark blue sapphires whether obtained from Ceylon, Australia, Siam, or Central Asia. These stones can be divided in two distinct classes; those which show a pure blue and a violet image, and those which show a blue and a yellow-green image under the dichroscopic lens. The former, which are never found among the Australian stones, are very refractory to the action of radium rays. In a few of them a trace of a violet coloration may be observed, but the rest remain absolutely unchanged in tint, even after weeks of radiation. The stones of the other class are altered slowly, but in a very striking manner by radium rays. Often they appear to shade toward violet after a few hour's radiation, but after two or three days a greenish tint appears, and in eight or ten days the color has become a dirty dark-green. This change of color, in contrast to the very fugitive change of the pale Ceylon stones, appears absolutely permanent at ordinary temperature even in bright sunlight, but the original color is restored by heating to about 200 deg. Cent.

The behavior of the artificial sapphires is still different. The colorless stones become grayish yellow, but never assume the brilliant color which radiation produces in the pale natural Ceylon stone. The color disappears quickly in the light and persists only a few weeks in darkness. The pale blue artificial stones never become yellow, but only assume a greenish tint, which is not affected by light, but is quickly destroyed by heating. The dark blue artificial stones either show no change under radium rays or become slightly greenish.

From all these observations I conclude that both artificial and natural sapphires can be divided in two distinct classes; the dark blue stones, upon which radium rays exert very little or no effect and the pale stones which are very easily affected by radium.

It is a very remarkable fact that the same phenomena are repeated in the case of the so-called blue rock salt. In many salt mines small masses and single crystals are found which show a blue color throughout or in spots. By close examination it is possible to recognize two distinct varieties, in one of which the crystals have a unform pure sky-blue tint, while the other variety is characterized by deep indigo-blue spots or even dark blue entire crystals. In some cases the color is so deep that light passing through a section 1/25 inch thick is colored deep blue. These two varieties show typical differences in their behavior toward radium rays. The sky-blue salt becomes paler after a few hours radiation, and its color is changed to a brownish yellow by twenty-four hours radiation. This variety, therefore, resembles the pale Ceylon sapphire in behavior. If on the other hand a thin section of the indigo variety of rock salt is laid upon a strong radium preparation, no change of color is observed in the first few days. After about two weeks the color shades toward violet and it finally becomes a deep claret. A specimen, originally very dark in color, showed no change even after six months' radiation, while a slightly paler specimen exposed at the same time showed the deep claret hue in some places and retained its original indigo color in others. The dark variety of rock salt, therefore, behaves essentially like those varieties of sapphire which are little affected by radium rays. It resembles such sapphires also in the fact that its color is not a bright, but a grayish blue. It would be rash to infer from this analogy an identity in the source of color of the sapphire and the blue rock salt, but these observations may ultimately aid in explaining this peculiar coloration of rock salt.

Lightning Spot Remover.—This preparation is for the purpose of removing spots of all kinds from woolen fabrics, making black cloth glossy, cleaning carpets, etc. It consists of 31 parts strong fluid ammonia, 93 parts potash soap tincture, 7.8 parts soda, 7.8 parts borax, 31 parts ether, 31 parts alcohol and 798.4 parts water. In making it up, the salts are dissolved in a suitable quantity of the water, then the other materials, and finally the alcohol and ether added. As the fluid readily evaporates and thereby loses efficiency, it must always be kept tightly corked.—*Neueste Erfindungen und Erfahrungen.*

Trade Notes and Formulæ

Neutrality of Soap.—The best test for the neutrality of soap and the easiest to carry out consists in allowing hot solution of sublimate to trickle on the dry soap. If but a trace of yellow color appears (Hg O), there is still free alkali in the soap.—*Uber Seifen, by Dr. Eichoff.*

Color Pencils for Writing on Glass, Porcelain and Metal.—Black: Lampblack, 10; wax, 40; tallow, 10 parts. White: Krems white, 40; wax, 20; tallow, 10 parts. Pale blue: Berlin-blue (light), 10; wax, 20; tallow, 10 parts. Dark blue: Berlin-blue (dark), 15; mucilage, 5; tallow, 10 parts. Red: Cinnabar, 20; wax, 20; tallow, 20 parts. Yellow: Chrome yellow, 10; wax, 20; tallow, 20 parts. Yellow: Cadmium yellow, 10; wax, 20; tallow, 20 parts.—*Der Chemisch-Technische Fabrikant.*

Priming for Metals.—The ordinary varnishes do not attach themselves to the surface of metals but merely coat them and soon crack off. This defect can easily be remedied if the metal, after being freed from grease by a pickle, is treated with an etching mixture, consisting of 15 parts nitric acid, 20 parts alcohol, 5 parts liquid gum arabic and 10 parts water. This mixture is applied as a thin coat. After it is dry, smooth with a polishing agate and the varnishing can then be done in the ordinary manner.—*Praktischer Wegweiser.*

Cement for Hard Rubber Goods.—Dissolve gutta percha in sulphide of carbon (combustible) until a thick fluid is obtained, so thick that it can only just be painted on, coat the broken parts on both surfaces of the break, paint them with chloride of sulphur solution (1:20) and press them together. It is advisable for a second person to smooth the pressed out cement with the back of a knife, in all directions, and after the mass is half dry, which will be in a few seconds, to go over the cemented place carefully with a hot iron. Only when the cement has set, which will also be in very short time, can the pressure be released. These repairs usually hold well because the gutta percha has been vulcanized and forms, with the ebonite, a homogeneous mass. Very often the cemented place is stronger, because the cement is somewhat elastic, than the ebonite, which possesses but moderate strength.—*Drogisten Ztg.*

To Readily Distinguish Cast Iron, Steel and Bar Iron.—On the surface, previously filed bright, or on the article itself if it is already bright, a drop of aqua fortis is placed. After the acid has been allowed to work a few minutes, it is wiped off and the place rinsed with water. In the case of bar iron, a dull-white ash-gray spot, with steel, a brownish-black, with cast iron, a deep black spot is distinctly visible, so that this simple operation suffices to readily distinguish the above-mentioned different materials from one another. By this means, we can readily determine whether a wrought iron object is edged with steel and how far the welding extends. The entire test is based on the varied proportions of carbon in the iron products, cast iron containing proportionately the largest quantity of carbon, steel coming next and then wrought iron, in percentages about 3:0.6:0.3. The effect of the nitric acid on the metal surface is to expose the carbon, the acid dissolving the iron. A similar phenomenon occurs when meteoric iron is exposed to the action of aqua fortis, peculiar figures being formed.—*Neueste Erfahrungen und Erfindungen.*

To Stick Drawings to Sheet Tin.—Paper can be attached to sheet tin only by means of an elastic, flexible adhesive, as otherwise it will peel off, owing to the expansion and contraction of the tin, due to changes in temperature. Such adhesives almost always contain sugar or syrup, that prevents brittleness. For this purpose the following adhesives may be used: 1. Water-glass, with a small addition of sugar syrup or starch syrup (glucose). This adhesive will even hold the paper fast to the metal when the latter is heated. 2. Glue-starch paste, made by mixing thick solution of hot glue with two parts of freshly prepared starch paste and stirring into the mixture one part of thick turpentine and one part of alcohol. This glue-paste holds very fast, and is notable because it does not pass through the paper. 3. Sixty parts of gum arabic are dissolved in as much water as may be needed for the boiling with it of forty-five parts of fine wheat starch. Then add the forty-five parts of fine wheat starch and fifteen parts of sugar to the solution and boil down to the desired consistency. This adhesive sticks fast and can be kept a long time in closed cans, if when boiling, a little camphor is added to it.—*Drogisten Ztg.*

Production of a Deep-black Coating on Copper and Its Alloys by the cold process. The process described by B. Müllaner makes it possible to coat objects of copper and its alloys with a firmly adherent, deep black layer of copper oxide, resistant to mechanical influences and which also withstand carbonic acid, ammonia, nitrogen and water. The objects, cleaned mechanically and treated with dilute sulphuric acid, are moved about for perhaps five minutes in a [illegible] per cent soda lye, at 100 deg. Cent., to which has been added one per cent of pulverized per-sulphate of potash. When the development of oxygen that occurs on the immersion, has ceased, add a further one per cent of per-sulphate of potash until the desired color is obtained. The articles are then rinsed with cold water, dried and rubbed off with a cloth. The stain can be used repeatedly, only when used again a new addition of per-sulphate of potash must be made. The thickness of the coating, its color and durability, are dependent on temperature, length of exposure and development of oxygen. If the temperature drops below 70 deg. Cent. we obtain a less durable coating which readily assumes a blue or yellowish tint. After prolonged use, the stain, owing to the formation of sulphur by the decomposition of the per-sulphate and its absorption of carbonic acid from the air, becomes ineffective. Copper alloy articles with varying proportion of copper, require a longer staining period, perhaps five to ten minutes. Articles of tin, zinc, aluminium, iron, nickel, German silver or soft solder must at first be heavily electrocoated with copper and then stained. By this means soldered places may be given exactly the same color as the rest of the metal.—*Electrochemische Zeitschrift.*

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